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STANDARDIZATION ENGINEERING PRACTICES STUDY FOR PRINTED WIRING BOARD AND ASSEMBLY DEFECTS GUIDE AND CONFORMAL COATINGS PROBLEM AREAS

Final Report

By
Walter S. Rigling

October 1975

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UNITED STATES ARMY ELECTRONICS COMMAND · FORT MONMOUTH, N.J.

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Orlando, Florida 32805

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OR 13,725

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ABSTRACT

The purpose of this program was to develop a military standard that contained corrective action guide data for printed wiring board and assembly defects and to develop test data from which revision drafts to MIL-I-46058 could be written.

This report describes the accomplishments of the final portion of the program. It also includes major portions of effort completed in previous semiannual portions of the program. The complete results of all contract goals are provided with emphasis placed on reversion, service temperature, and buffer material analysis.

The Phase I portion is provided as an appendix to this report and sets forth those features necessary to achieve the goals selected.

The Phase II effort demonstrated that a quantitative test procedure could be developed that would measure change in properties of the various materials as they age or deteriorate under thermal and moisture conditions. The buffer material tests strongly indicate the need for buffer materials only if coating thicknesses are greater than 6 mils.

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FOREWORD

This standardization study was conducted simultaneously under two phases as follows:

Phase I - Defect Analysis

To develop a military standard to contain corrective action guide data for printed wiring board and assembly defects; and to include this data in military documents such as MIL-P-13949, MIL-P-55110, MIL-P-55640, MIL-STD-275, and MIL-STD-1495, as applicable.

Phase II - Conformal Coatings

To develop revision drafts to applicable specifications or standards, to add a standardized accelerated reversion test, and to provide criteria for specifying "buffer" materials, service temperatures, and solvent resistance characteristics of the conformal coatings. The documents involved are MIL-I-46058, MIL-P-55110, MIL-STD-275, and MIL-STD-1495, as required.

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I. TECHNICAL DISCUSSION

A. INTRODUCTION

Defects arising from the handling of printed wiring board materials, their processing, and fabrication are frequently repeated, thus causing delivery delays and increased costs. To prevent this, a guide was developed which provides identification, cause, and corrective action criteria for those defects set forth in various military specifications. Through the use of this document, the printed wiring board supplier can reduce the frequency of repetition and increase efficiency.

The main purpose of conformal coating materials is to protect printed wiring board assemblies from environmental and mechanical damage. While the available materials have generally met these requirements successfully, sufficient information is not available in four major areas:

1 Reversion Resistance - Field reports have indicated the occurrence of certain coatings reverting to an unpolymerized condition after exposure to heat and moisture. A test for detecting reversion in susceptible materials is needed.

2 Service Temperature - The effect of long term exposure to elevated temperatures must be measured to determine the limiting temperature at which each material can safely operate.

3 Solvent Resistance - With the need to remove oils and other inprocess residue, the conformal coating may be subjected to degrading solvents, thus necessitating an evaluation of the materials under simulated cleaning conditions.

4 Buffer Materials - While most assembly specifications require the application of a protective sleeving over brittle components prior to coating, some doubt has been expressed as to the best form of protection and the necessity for any protection when using flexible coating materials. The second phase of this program has been directed toward the investigation of these areas of concern.

B. PHASE I - DEFECT ANALYSIS GUIDE

The development of an effective and comprehensive Defect Analysis Guide has progressed through several phases with the final form and content as delineated in Appendix A. The initial approach was directed toward a highly detailed analysis of several broad areas containing defects with similar causes and corrective action. This approach contained the essential information desired, but it did not contain a means for directly referencing each defect in the various specifications with the necessary corrective action.

The data accumulated from the above effort was used to formulate a second approach which was used through the remainder of the program. Specifications MIL-P-55617, MIL-G-55636, MIL-P-13949, MIL-STD-1495, MIL-P-55110, and MIL-P-55640 were analyzed and all defects set forth in the form of a matrix. The matrix included the specification number, the paragraph or defect reference designation, and the definition.

The final form of the guide includes sections for basic materials and detail boards. The paragraph numbers are taken from MIL-P-55617A, MIL-G-55636A, MIL-P-13949E, MIL-STD-1495, MIL-P-55110B Amendment 2 and MIL-P-55640A Amendment 1 and may change as these specifications are revised. However, the defect identification will not change as a result of specification amendments or revisions. While it was originally planned to include a section covering assembly defects in the guide, present assembly specifications do not address themselves to assembly oriented defects, except for a reference to damaged terminals and improperly installed components. However, the guide is structured so that as assembly defects become established as cause for rejection, they can be readily added to this section.

C. PHASE II - CONFORMAL COATINGS

1. Reversion Resistance and Service Temperature

a. Test Procedure Survey

The development of a test procedure that would provide quantitative results in a much shorter time than the 120 days presently specified in MIL-I-46058 has been a major goal of this program. The fact that much independent and government funded effort has been expended in this area is testimony to the level of difficulty of the problem. In this program several approaches were evaluated with varying levels of success.

The following procedures were developed for detecting reversion at 85°C and 97 percent RH somewhat sooner than 120 days:

1 Use of increased atmospheric pressure at 85°C and 97 percent relative humidity. This method did not increase reversion rate. (See first semiannual report.)

2 Measurement of hardness using 1/8 inch thick specimens. Since it was found that reversion is a phenomenon which progresses from the surface inward, the detection of a change in hardness was not possible until well beyond 120 days for most materials. Certain materials such as the one part materials and those that contain solvents could not be cast in 1/8 inch thick sections.

3 Thin coatings applied by dipping 1 inch X 4 inch aluminum plates. These coatings were tested using a Rockwell microhardness tester; however, an ink suitable for indicating depth of penetration could not be found.

4 Pencil hardness measured on aluminum panels prepared as above. The test method was in accordance with MIL-P-27316. Measurements were made throughout a 120 day test period (85°C, 97 percent RH). The results were not consistent or reproducible.

5 Bend testing. Thin aluminum sheets were coated with test materials. These sheets were then subjected to bending over various radii to develop a crack initiation baseline so that changes in flexibility could be measured as test exposure progressed. The individuality of each material required the development of test characteristics for each. This procedure was discontinued because of this extreme complexity.

6 Tensile strength and elongation - ASTM A412-64T. This used the common "dog bone" specimen. Several sheets of each material were cast on glass plates on a horizontal plane that allowed the material to seek its own thickness during cure. These sheets were then identified and cut into tensile specimens. Several specimens of each material were tested for tensile strength and elongation immediately after curing to establish baseline strength. The characteristics of the one part materials and the solvent based materials were such that sufficiently thick and void free specimens could not be cast. Since this would eliminate it as a universally applicable test procedure, no further work was performed on it.

7 Attempts to measure dielectric constant and dissipation factor. The results were too widely dispersed to form a baseline for continued comparison after exposure.

8 Resin acetone extraction. It was theorized that since the "B" staged or partially cured resin in a prepreg can be measured by extracting the unpolymerized components with acetone, as hydro depolymerization occurs in a cured resin, these components could also be extracted and the specimen would lose weight. After the evaluation of several solvents, no clear cut trend could be measured in all materials.

9 Infrared spectrophotometry. This method required expensive equipment; however, if the change in each material could be detected by this method, it would be valuable reference data for a more straightforward test procedure. The loss of C=N linkage could be detected in a urethane that was known to revert, but no change could be detected in an epoxy that was known to revert. While this method could not be used for further testing, it conclusively showed that reversion in the early stages is a surface phenomenon and that thick specimens could not be expected to provide short term test results.

All of the above procedures provided some insight into the problem but none exhibited all of the desirable characteristics which were the goals of this portion of the program - that the need for specialized or expensive equipment be minimized, that the results would be quantitative, that the results be reproducible, and that the time required to detect reversion be reduced well below 120 days.

Based on a thorough review of the results of the previous attempts, it was concluded that any method developed should utilize thin coatings, that mechanical strength such as tensile and elongation retention should be the measured characteristic, and that non-specialized equipment be utilized to perform the test. The method chosen was a peel test.

The specimen consisted of coating a 1 1/2 inch wide and 8 inch long etched printed wiring board specimen with the test material and placing a 1 inch wide strip of fabric on the uncured material. The coating was then cured and the mechanical properties measured prior to and during exposure by peeling 1 inch of fabric at right angles to the printed wiring board.

First attempts using glass, nylon, and dacron fabric were unsuccessful since several of the more rigid resins caused the fabric to become inflexible and they broke rather than peeled. The most successful material was common 16 x 16 copper screening. Several thicknesses of coating were also tried and it was found that consistent results could be obtained using 0.005 to 0.007 inch thicknesses.

The specimen configuration is shown in Figure 1. This approach uses materials representative of those actually used in printed wiring assemblies, a coating thickness also typical of those actually used, and a test fixture and method similar to that used to test for copper foil bond strength. Most significant is the fact that this approach quantitatively measures the peel strength, and therefore, the tensile and elongation of the thin film coating. It has proven to be reproducible.

b. Test Results and Analysis

The peel test described above was used to measure the resistance to thermal degradation and reversion at 85°C, 105°C, and 125°C.

Two sets of three specimens were prepared using all materials qualified to MIL-I-46058 with the inclusion of an epoxy that was known to revert (#19) and with the exception of the type XY materials which were too thin to provide meaningful quantitative results when tested in this manner. Six peel specimens were made from each material: three for thermal and three for reversion testing.

Using the 85°C temperature as the baseline and Arrhenius plots as the criteria, 105°C should cause deterioration four times faster and 125°C sixteen times faster than the baseline temperature. An equivalent day would, therefore, be 6 hours at 105°C and 1.5 hours at 125°C. So, at 105°C, 120 equivalent days would take 20 real days to cause the same chemical reaction as at 85°C. At 125°C, 7.5 days would provide the same results as 85°C for 120 days.

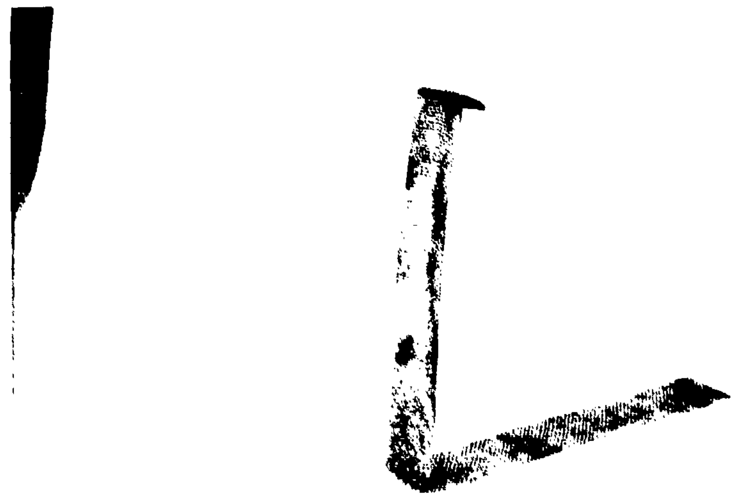

Figure 1 - Peel Specimen

The major consideration of this assumption is that over the period of time involved and the test temperatures selected, significant chemical degradation will not occur as a result of the temperature itself.

The thermal test specimens were placed in air circulating ovens at the prescribed temperature. The air introduced into the ovens was directly from laboratory ambient conditions which varied from 30 to 60 percent in relative humidity. The effect of the above temperatures on the various materials may be classified into three major groups. Those showing little effect were materials 2, 13, 17, 20 (all UR's), and 4 (SR); those with slight decrease in strength were 3, 11, 14, 15, 18 (UR's), 8, and 12 (ER's); and those with significant decline were 6, 7, and 9 (all ER's). In all but five cases (4-SR, 9-ER, 19-UR, 17-UR, and 26-SR), there was an increase in strength after the first day of exposure to temperature. This greater value would then be maintained or gradually decline throughout the test period. While all materials were prepared and cured in accordance with the manufacturer's instructions, the initial increase would indicate that the recommended cure cycle was inadequate.

The humidity test specimens were exposed to the three temperatures (85°C, 105°C, and 125°C) with the humidity maintained above 95 percent. A standard cabinet type chamber was used for the 85°C test and a pressure vessel with calibrated pressure indicators and electronically controlled temperature sources was used for the 105°C and 125°C tests. In all cases the as-cured, unexposed specimens were tested for peel strength to establish a baseline value; then additional peel strength tests were performed after 1, 6, 14, 32, 84, and 120 equivalent day intervals. The complete test results are shown in Table I.

Without exception a distinct decrease in strength was apparent after the first and sixth day with a leveling trend occurring after that. It is assumed that this is the result of hydroplasticization and not an indication of reversion. From this point on, the materials either maintained the 6 to 14 day strength value throughout the 120 day period or gradually lost strength until the value was no longer measurable (1 lb/inch).

The overall humidity exposure results may be classified into four major categories: those that maintained a constant and measurable value throughout the test; those that failed between 84 and 120 days; those that failed between 32 and 84 days; and those that failed between 14 and 32 days. One material, a one part AR material, exhibited acceptable strength after each exposure; however, it was apparent that even at the 85°C test temperature the material would reflow each time. This phenomenon began to occur after the 6 to 14 day period. It was soft and almost fluid at the test temperature but hardened when cooled to room temperature. This indicated the probability of leveling on horizontal surfaces and the reduction of thickness on vertical surfaces when the assembly was subjected to these temperatures.

MATERIAL TYPE AND CODE	SPECIMEN	AS RECEIVED						1 DAY						
		TEST TEMPERATURE						TEST TEMPERATURE						
		85°C		105°C		125°C		85°C		105°C		120°C		
		DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY
UR 2	A	19.0	19.0	18.0	22.0	22.5	19.5	19.5	17.0	18.5	19.0	22.5	14.8	19.0
	B	18.5	19.5	17.0	20.0	19.0	19.5	18.0	16.0	17.5	19.0	20.5	15.5	18.5
	C	17.5	19.2	20.0	22.0	21.5	21.0	17.5	16.5	19.0	18.0	22.0	13.5	19.0
UK 3	A	17.0	19.0	14.0	19.0	16.0	14.0	16.0	15.0	13.0	17.0	14.0	9.5	16.5
	B	14.0	19.0	17.0	20.5	17.0	18.0	15.5	16.5	17.5	14.0	18.0	11.5	18.0
	C	14.0	19.0	14.0	18.0	17.0	18.0	16.5	15.5	14.0	15.0	14.0	12.5	18.0
SR 4	A	6.8	7.5	7.8	7.0	6.2	3.5	6.0	4.0	6.5	4.0	6.0	8.0	6.5
	B	7.0	6.4	4.2	7.2	7.0	3.2	7.0	3.5	5.5	5.0	8.0	6.0	5.5
	C	7.8	7.5	5.3	7.2	4.2	3.7	8.5	4.5	6.0	5.5	5.0	7.0	8.0
ER 6	A	9.0	11.5	8.0	13.5	9.6	6.0	12.0	7.5	9.0	8.0	9.0	6.5	12.0
	B	11.5	10.8	10.0	12.5	6.8	7.2	12.0	6.0	12.5	8.5	8.0	6.0	14.0
	C	10.5	10.2	11.0	12.0	10.2	11.0	11.5	5.5	[illegible]	7.5	9.0	7.0	15.0
ER 7	A	10.0	9.8	16.5	9.0	6.2	7.2	12.0	7.0	11.5	5.5	9.5	6.0	10.0
	B	7.0	10.0	9.5	7.0	7.0	8.0	10.5	8.5	11.5	4.5	10.0	5.0	9.5
	C	8.8	9.2	7.2	9.2	7.2	8.0	12.5	3.5	7.5	6.0	7.0	5.0	12.5
ER 8	A	10.8	13.0	7.0	14.0	6.0	8.0	12.5	6.0	7.0	7.0	7.0	7.0	11.0
	B	9.5	10.0	10.5	14.0	8.0	12.0	10.5	3.5	10.0	8.5	10.0	6.0	10.5
	C	9.8	10.5	8.5	9.8	9.2	9.0	10.5	5.0	9.0	7.5	11.5	5.5	10.5
ER 9	A	8.0	7.5	11.0	8.7	9.2	8.0	9.5	4.0	12.5	5.5	9.0	6.5	8.5
	B	8.0	8.8	6.8	9.5	7.0	6.0	9.0	5.0	8.0	6.5	9.5	7.0	6.5
	C	6.2	9.2	8.5	8.0	7.5	7.0	11.0	5.0	11.5	6.0	10.0	6.5	8.0
UR 11	A	11.0	9.8	8.0	9.2	8.5	8.0	12.0	8.0	8.5	10.0	10.0	9.0	11.5
	B	7.2	9.0	7.5	7.5	9.0	7.0	12.0	6.0	8.0	11.0	13.0	7.0	10.5
	C	6.8	9.8	6.5	12.5	7.5	7.0	11.0	7.0	7.0	12.0	9.0	5.5	12.5
ER 12	A	12.0	10.0	7.2	9.5	8.0	13.0	10.5	3.5	8.0	5.5	7.0	9.5	9.5
	B	9.8	8.2	7.5	10.5	9.0	14.0	10.5	3.5	8.5	6.5	9.0	11.5	10.5
	C	9.2	9.0	8.0	11.5	8.0	22.0	11.0	4.0	7.5	6.0	12.0	13.0	8.5
UR 13	A	6.2	4.8	4.8	5.5	4.0	4.5	5.5	2.5	5.0	>1.0	4.5	2.5	5.5
	B	4.2	5.8	5.0	5.2	5.2	5.5	4.5	2.5	4.5	1.0	5.5	2.5	5.5
	C	6.2	5.2	5.6	6.0	4.2	4.0	7.0	2.0	4.0	1.0	3.5	2.0	6.5

TABLE I

Thermal and Humidity Exposure Test Summary

CUMULATIVE TEST TIME-DAYS*																		
		6 DAYS						14 DAYS						32 DAYS				
E		TEST TEMPERATURE						TEST TEMPERATURE						TEST TEMPERATURE				
120°C		85°C		105°C		120°C		85°C		105°C		125°C		85°C		105°C		
RY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DR
.5	14.5	19.0	13.0	22.0	12.5	23.0	14.5	21.0	13.5	21.0	17.0	24.0	15.0	21.0	15.0	20.0	14.0	2
.5	15.5	18.5	.55	21.0	13.5	22.0	16.0	14.0	14.5	21.0	17.0	23.0	16.0	19.0	15.0	19.5	14.0	21.
.0	13.5	19.0	15.0	22.0	15.0	24.0	14.5	21.0	16.0	22.0	15.0	24.0	13.0	21.0	17.0	23.0	15.0	25
0	9.5	16.5	13.5	18.0	15.0	16.0	8.0	17.0	14.0	18.0	14.0	16.0	7.5	12.5	13.0	17.0	10.0	16
.0	11.5	18.0	13.0	20.0	13.5	17.0	11.5	18.5	13.5	23.0	12.5	17.0	7.0	16.0	13.0	21.0	10.0	17
.0	12.5	18.0	15.0	17.0	15.0	14.0	11.5	18.0	12.5	17.0	15.0	15.0	7.0	17.0	12.0	17.5	14.0	14
.0	8.0	6.5	3.0	5.0	2.0	5.5	7.5	6.5	3.5	4.5	2.0	7.5	6.5	6.5	2.5	5.0	2.0	8.5
.0	6.0	5.5	3.5	5.5	3.5	8.0	6.0	5.0	3.0	5.0	3.5	9.0	6.0	6.5	2.5	5.0	3.5	9.0
.0	7.0	8.0	3.5	4.5	2.5	4.5	8.0	5.0	3.5	6.0	2.0	4.5	6.0	5.0	3.0	6.5	2.0	4.5
.0	6.5	12.0	6.5	12.0	6.0	10.0	6.5	12.5	5.5	10.0	7.5	7.0	5.0	11.0	2.5	10.0	6.0	8.5
.0	6.0	14.0	6.0	13.0	6.0	8.0	6.5	11.0	4.5	12.0	5.5	8.5	5.0	9.0	2.0	12.0	6.5	8.0
.0	7.0	15.0	4.5	15.0	6.5	9.0	6.5	13.0	3.0	11.5	6.5	10.0	7.0	11.0	>22.0	11.0	5.5	8.0
5	6.0	10.0	8.0	10.0	5.0	7.0	5.5	10.5	5.5	10.0	5.0	6.0	5.5	11.0	2.0	11.5	4.5	6.0
0	5.0	9.5	7.0	11.5	4.0	10.5	5.5	10.0	5.5	10.5	3.0	11.0	6.0	10.0	3.0	10.5	4.0	9.0
.0	5.0	12.5	7.0	8.0	5.0	7.0	5.5	12.0	5.0	5.0	6.0	6.5	5.5	11.0	2.5	5.5	5.0	6.0
0	7.0	11.0	5.0	10.0	5.5	6.0	7.5	12.5	3.5	8.5	4.5	5.0	5.5	11.0	2.5	7.5	6.0	5.0
0	6.0	10.5	3.0	11.0	6.5	12.0	5.5	10.5	1.5	10.0	6.5	12.0	5.0	9.0	1.0	13.0	5.5	10.0
5	5.5	10.5	3.5	9.0	5.5	11.5	5.0	11.0	2.0	8.0	5.0	11.0	6.0	11.0	>22.0	7.0	5.5	10.0
0	6.5	8.5	6.5	10.0	4.5	10.0	6.5	7.0	5.0	10.0	4.5	7.5	7.0	9.0	2.0	9.5	4.5	8.0
5	7.0	6.5	5.0	8.0	5.0	7.0	6.0	7.0	5.0	6.0	6.5	7.5	5.0	9.0	2.5	5.5	5.5	7.0
.0	6.5	8.0	5.5	9.0	4.0	6.0	5.0	7.0	4.5	6.5	4.5	5.5	6.5	7.0	2.5	6.5	5.5	6.0
0	9.0	11.5	7.5	10.0	6.0	10.0	10.5	12.0	8.0	10.5	6.0	7.5	9.0	16.0	8.0	8.0	7.0	8.0
.0	7.0	10.5	7.0	9.0	7.5	12.0	6.5	13.0	7.0	9.	7.0	12.0	7.0	13.0	7.0	9.5	6.5	13.0
[illegible]	5.5	12.5	6.5	8.0	7.5	8.0	8.0	14.0	8.0	8.0	8.0	9.0	7.0	13.0	8.0	10.0	8.5	11.0
0	9.5	9.5	2.0	8.0	4.5	4.0	8.5	9.0	2.0	6.5	4.0	6.0	7.5	8.0	1.5	6.0	3.0	4.0
[illegible]	11.5	10.5	2.0	10.0	4.5	9.0	10.5	9.0	2.0	6.5	4.5	8.0	10.5	8.0	1.0	6.0	3.5	7.0
0	13.0	8.5	3.0	8.5	3.0	11.0	12.5	8.5	2.0	6.0	3.5	10.0	11.0	7.0	1.2	5.0	3.0	7.0
5	2.5	5.5	2.5	5.0	4.0	7.0	2.0	6.5	2.5	6.0	<1.0	13.0	1.0	6.0	1.5	5.5	<1.0	9.0
5	2.5	5.5	2.0	4.5	1.0	5.0	2.0	6.0	2.0	7.0	<1.0	6.5	1.0	6.0	2.0	5.5	<1.0	6.0
5	2.0	6.5	1.5	5.0	1.5	4.0	3.5	5.5	2.0	6.5	<1.0	3.5	1.0	5.0	1.5	6.5	<1.0	4.5

32 DAYS					84 DAYS						120 DAYS					
TEST TEMPERATURE					TEST TEMPERATURE						TEST TEMPERATURE					
	105°C		125°C		85°C		105°C		125°C		85°C		105°C		125°C	
MID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID
.0	20.0	14.0	23.0	13.5	12.5	12.5	17.0	1.5	22	3.5	23.0	8.0	18.0	<1.0	20.0	<1.0
5.0	19.5	14.0	21.0	9.0	21.0	14.0	17.0	<1.0	20	2.5	21.0	9.0	18.0	<1.0	21.0	<1.0
.0	23.0	15.0	25.0	14.0	21.5	14.0	20.0	<1.0	23	3.5	21.0	8.0	19.0	<1.0	12.0	<1.0
.0	17.0	10.0	16.0	7.0	15.0	10.0	14.0	>1.0	16.0	2.5	18.0	5.0	14.0	2.0	15.0	<1.0
.0	21.0	10.0	17.0	6.0	16.0	8.0	17.0	<1.0	13.0	1.5	17.0	4.5	18.5	3.5	15.5	<1.0
.0	17.5	14.0	14.0	6.0	17.0	10.0	16.0	1.0	14.0	2.0	16.0	5.0	15.0	1.5	19.0	<1.0
.5	5.0	2.0	8.5	5.5	6.5	3.0	6.0	>1.0	8.5	3.0	6.5	3.0	6.5	<1.0	9.5	3.0
.5	5.0	3.5	9.0	2.5	6.5	2.5	6.0	2.5	7.0	1.5	7.0	2.5	5.5	<1.0	8.5	1.5
0	6.5	2.0	4.5	3.5	6.0	3.0	7.0	>1.0	5.0	2.0	5.0	2.5	7.0	<1.0	5.5	2.0
.5	10.0	6.0	8.5	5.0	10.0	<1.0	8.0	4.0	6.0	4.5	7.0	<1.0	5.0	4.0	6.5	4.5
.0	12.0	6.5	8.0	5.5	8.5	<1.0	8.0	3.5	6.5	5.0	7.5	<1.0	7.0	4.0	6.0	4.5
.0	11.0	5.5	8.0	7.0	9.5	<1.0	8.0	3.0	7.0	6.0	7.0	<1.0	7.5	4.5	6.0	5.0
.0	11.5	4.5	6.0	5.0	10.0	<1.0	8.0	3.0	4.5	5.0	7.0	<1.0	7.0	3.5	5.5	5.0
0	10.5	4.0	9.0	5.5	10.0	<1.0	8.0	2.0	6.5	5.0	5.5	<1.0	8.0	3.0	7.0	5.0
.5	5.5	5.0	6.0	6.0	11.0	<1.0	4.0	2.0	5.0	5.0	7.0	<1.0	4.0	2.5	5.5	5.0
5	7.5	6.0	5.0	6.5	10.0	<1.0	7.0	4.0	4.0	5.5	8.0	<1.0	6.0	4.0	4.0	6.0
0	13.0	5.5	10.0	5.0	10.0	<1.0	9.0	5.0	8.5	4.5	7.0	<1.0	10.0	3.5	9.5	4.5
.0	7.0	5.5	10.0	4.5	7.5	<1.0	6.0	3.5	9.0	4.5	7.0	<1.0	6.0	3.0	10.0	3.5
.0	9.5	4.5	8.0	6.5	7.5	<1.0	6.0	4.0	6.5	6.0	7.0	<1.0	7.0	3.0	5.5	5.5
5	5.5	5.5	7.0	5.5	6.5	<1.0	3.5	4.0	5.0	5.0	6.0	<1.0	3.0	3.5	6.0	4.5
5	6.5	5.5	6.0	5.5	5.5	<1.0	5.0	5.0	4.5	5.0	5.0	<1.0	4.5	4.0	4.0	5.5
0	8.0	7.0	8.0	9.0	15.5	9.0	11.0	1.0	8.0	4.5	16.0	8.0	10.0	<1.0	9.0	1.5
0	9.5	6.5	13.0	5.5	13.5	7.0	10.0	<1.0	11.5	3.5	15.0	6.0	8.0	<1.0	11.0	1.5
0	10.0	8.5	11.0	7.0	14.0	8.0	10.0	<1.0	9.0	3.5	14.0	5.5	11.0	<1.0	9.0	1.5
5	6.0	3.0	4.0	7.0	6.5	<1.0	7.0	2.0	5.5	7.0	4.5	<1.0	8.0	2.0	6.5	7.0
0	6.0	3.5	7.0	10.0	7.0	<1.0	5.0	3.0	7.0	9.0	7.0	<1.0	6.5	2.5	6.5	10.0
2	5.0	3.0	7.0	10.0	7.5	<1.0	6.	1.5	7.0	10.0	6.0	<1.0	7.5	2.0	8.0	10.0
5	5.5	<1.0	9.0	<1.0	6.5	2.0	7.0	<1.0	10.5	<1.0	7.0	2.0	8.0	<1.0	12.0	<1.0
.0	5.5	<1.0	6.0	<1.0	6.5	2.0	8.0	<1.0	6.5	<1.0	9.0	2.5	7.5	<1.0	8.0	<1.0
5	6.5	<1.0	4.5	<1.0	6.0	1.5	7.5	<1.0	5.0	<1.0	9.0	2.5	10.0	<1.0	5.0	<1.0

3

MATERIAL TYPE AND CODE	SPECIMEN	AS RECEIVED						1 DAY						TES[T TEMPERATURE]	
		TEST TEMPERATURE						TEST TEMPERATURE							
		85°C		105°C		125°C		85°C		105°C		120°C		85°C	
		DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID
UR 14	A	9.2	9.5	12.2	9.5	10.0	9.5	10.5	7.0	11.5	6.0	10.0	5.0	11.5	5.0
	B	10.0	8.5	10.0	7.5	10.0	11.0	12.5	7.5	10.0	5.0	9.0	5.5	12.0	6.0
	C	9.8	10.0	8.0	8.2	6.2	11.5	11.5	7.0	10.5	5.5	8.5	6.5	11.5	7.0
UR 15	A	16.0	14.0	15.0	17.0	13.0	14.0	9.5	6.0	13.5	9.5	14.0	8.5	10.0	5.0
	B	17.0	12.0	15.0	12.0	12.0	13.0	9.0	7.5	12.0	7.0	6.0	7.0	8.0	6.0
	C	13.0	16.0	14.0	13.0	14.0	16.0	9.5	8.5	6.0	5.5	12.5	9.0	8.0	7.0
UR 17	A	10.0	11.0	11.0	10.5	9.5	10.0	9.0	8.0	9.0	6.5	8.5	6.5	9.5	9.0
	B	11.0	10.0	12.0	11.0	10.5	10.5	10.5	9.0	9.5	8.0	8.5	6.0	9.0	9.5
	C	12.0	11.0	11.0	12.0	9.5	10.0	9.5	8.5	9.0	7.0	9.5	6.0	9.0	9.5
UR 18	A	11.0	12.0	12.8	11.5	12.5	11.5	14.0	11.0	15.0	15.0	18.0	15.0	13.5	11.0
	B	9.7	11.5	11.0	10.5	11.8	12.0	14.5	10.5	17.0	14.0	17.0	17.0	12.5	11.5
	C	11.5	13.5	11.5	11.5	12.8	11.8	16.0	12.0	16.0	15.0	17.0	15.0	14.5	12.5
ER 19	A	23.0	14.0	24.0	21.0	29.0	25.0	28.0	7.6	27.0	13.0	32.0	6.5	>40.0	7.5
	B	18.0	24.0	32.0	24.0	28.0	23.0	28.0	11.0	30.0	12.0	38.0	7.5	>40.0	7.5
	C	12.0	19.0	27.0	22.0	24.0	27.0	12.0	12.0	44.0	12.0	40.0	6.0	13.0	5.5
UR 20	A	20.0	18.0	12.0	18.0	14.0	15.0	19.0	18.0	16.0	11.0	20.0	19.0	19.0	16.5
	B	20.0	20.0	13.0	21.0	11.5	14.5	19.5	18.0	17.5	11.5	20.0	16.5	18.5	19.0
	C	19.0	21.0	13.0	17.5	12.5	12.0	18.0	17.0	19.0	12.5	18.0	17.0	18.5	20.0
AR 21	A	15.0	18.0	18.0	19.5	16.5	16.0	17.0	12.5	15.0	13.5	6.0	11.0	14.5	3.5
	B	20.5	19.5	24.0	16.2	21.0	18.0	15.0	6.5	23.0	10.5	15.0	11.0	18.0	2.0
	C	19.5	22.0	18.0	17.0	17.0	22.0	15.0	4.5	9.0	9.0	8.0	11.0	14.0	2.0
SR 25	A	2.7	2.6	3.8	2.8	4.2	3.2	4.0	5.5	5.0	5.5	7.0	7.0	4.0	5.0
	B	2.6	2.8	3.6	3.0	3.0	3.4	4.0	6.0	5.5	6.5	5.5	6.5	4.5	6.0
	C	2.2	2.8	3.7	2.5	3.3	3.6	3.5	6.5	6.5	6.0	6.5	7.5	4.5	5.5
SR 26	A	7.8	5.7	5.2	6.3	6.7	3.8	8.0	4.5	6.5	3.5	7.0	2.5	7.5	5.0
	B	6.8	6.7	7.0	6.4	6.2	4.7	6.5	6.0	7.5	4.0	6.5	4.0	6.5	5.5
	C	6.3	5.8	7.2	5.8	5.8	5.0	6.5	5.0	6.6	4.0	6.5	4.0	6.5	4.0
	A														
	B														
	C														

TABLE I - Continued

		CUMULATIVE TEST TIME-DAYS*															
		6 DAYS						14 DAYS						32 DAYS			
URE		TEST TEMPERATURE						TEST TEMPERATURE						TEST TEMPERATUR			
120°C		85°C		105°C		120°C		85°C		105°C		125°C		85°C		105°C	
DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID
10.0	5.0	11.5	5.0	13.0	3.5	12.0	6.5	10.0	4.5	11.0	2.5	13.0	3.0	12.0	2.0	10.5	2.0
9.0	5.5	12.0	6.0	11.0	2.5	11.5	6.5	10.5	4.5	10.5	2.0	12.0	3.5	9.0	1.5	12.0	1.5
8.5	6.5	11.5	7.0	10.5	1.5	12.0	6.0	11.5	5.0	7.5	2.5	11.0	3.5	12.0	2.0	5.5	1.5
14.0	8.5	10.0	5.0	5.0	6.0	5.5	7.5	9.5	5.5	10.0	4.0	7.0	8.0	10.0	3.0	7.0	1.5
6.0	7.0	8.0	6.0	11.0	4.0	8.0	7.5	9.0	6.0	11.5	3.0	8.5	6.0	8.5	3.5	10.0	1.5
12.5	9.0	8.0	7.0	9.0	4.5	11.0	9.0	7.0	6.0	8.0	2.5	10.0	7.0	6.5	5.0	6.0	2.0
8.5	6.5	9.5	9.0	10.0	5.5	9.0	6.5	9.0	10.0	10.0	5.0	8.0	7.0	10.0	9.5	10.0	5.0
8.5	6.0	9.0	9.5	9.5	6.0	9.0	6.5	9.5	10.5	9.0	5.0	9.0	6.0	11.0	11.0	10.0	5.0
9.5	6.0	9.0	9.5	10.5	6.0	9.0	7.5	10.0	10.0	8.5	4.5	8.0	6.5	9.5	10.0	9.0	4.5
18.0	16.0	13.5	11.0	16.0	10.0	16.0	13.0	12.5	10.0	11.0	8.0	12.5	13.0	12.0	11.0	13.0	7.5
17.0	12.0	12.5	11.5	15.5	9.5	16.0	15.5	10.5	12.0	12.5	7.0	12.0	12.5	13.0	12.0	11.0	7.5
17.0	15.0	14.5	12.5	16.0	10.5	17.0	17.0	13.5	12.0	11.5	8.5	13.0	14.0	12.5	13.0	11.0	9.0
32.0	6.5	>40.0	7.5	26.0	2.5	>40.0	5.0	>40.0	2.0	23.0	<1.0	>40.0	2.0	>40.0	<1.0	>40.0	<1.0
38.0	7.5	>40.0	7.5	35.0	3.0	>40.0	8.0	28.0	1.5	>40.0	<1.0	<40.0	4.5	>40.0	<1.0	>40.0	<1.0
40.0	6.0	12.0	5.5	>40.0	3.5	>40.0	7.0	12.0	2.0	>40.0	<1.0	<40.0	2.5	>40.0	<1.0	>40.0	<1.0
20.0	19.0	19.0	16.5	18.0	7.5	22.0	16.0	19.5	17.5	21.0	2.5	24.5	15.0	22.0	18.0	19.5	<1.0
20.0	16.5	18.5	19.0	19.0	6.5	22.0	18.0	19.0	18.0	19.0	2.0	23.0	14.0	18.0	18.0	21.0	1.5
18.0	17.0	18.5	20.0	20.0	7.0	18.0	17.0	20.0	19.0	17.0	3.0	18.0	13.0	19.0	11.0	19.5	1.0
6.0	11.0	10.5	3.5	6.0	5.5	6.0	8.0	13.0	3.0	9.0	6.0	7.0	3.5	11.0	3.5	11.0	6.0
15.0	11.0	18.0	2.0	18.0	4.5	10.0	12.5	17.0	4.0	12.0	7.0	11.0	3.5	14.0	3.0	9.0	8.0
8.0	11.0	14.0	2.0	9.0	3.0	9.0	12.0	12.0	5.0	9.0	6.0	9.0	4.0	9.0	4.5	9.0	7.0
7.0	7.0	4.0	5.0	6.0	2.5	6.0	7.5	4.5	6.0	6.0	1.5	6.0	5.5	4.5	3.0	6.5	1.5
5.5	6.5	4.5	6.0	6.0	4.0	7.0	6.5	4.5	5.0	6.0	2.0	5.5	4.5	4.0	4.5	6.5	1.5
6.5	7.5	4.5	5.5	6.5	3.0	6.5	7.0	5.0	5.5	6.5	2.5	6.0	6.0	6.0	4.5	8.0	2.0
7.0	2.5	7.5	5.0	7.5	2.0	7.5	3.5	8.0	4.0	7.5	2.0	7.5	2.5	7.0	4.0	8.0	3.0
6.5	4.0	6.5	5.5	8.0	4.0	8.0	3.0	7.0	5.0	8.0	3.0	7.5	2.5	7.5	4.5	7.5	2.0
6.5	4.0	6.5	4.0	7.0	3.5	6.5	4.0	6.5	3.5	7.0	3.5	7.0	3.5	6.0	2.5	7.5	3.0

32 DAYS				84 DAYS						120 DAYS					
T TEMPERATURE				TEST TEMPERATURE						TEST TEMPERATURE					
105°C		125°C		85°C		105°C		125°C		85°C		105°C		125°C	
DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID	DRY	HUMID
10.5	2.0	10.5	2.0	10.5	1.5	8.5	<1.0	8.5	<1.0	11.0	1.0	7.5	<1.0	9.5	<1.0
12.0	1.5	10.0	1.5	10.0	1.0	8.0	<1.0	8.0	<1.0	10.0	1.0	9.0	<1.0	10.0	<1.0
5.5	1.5	11.0	2.0	11.5	1.0	7.5	<1.0	8.0	<1.0	11.5	1.0	5.5	<1.0	8.0	<1.0
7.0	1.5	5.5	1.5	8.5	1.0	8.5	<1.0	6.5	<1.0	7.5	1.0	8.0	<1.0	7.0	<1.0
10.0	1.5	7.0	2.0	8.5	1.0	10.0	<1.0	8.0	<1.0	9.0	1.0	7.0	<1.0	8.0	<1.0
6.0	2.0	16.5	1.5	7.0	1.0	6.0	<1.0	13.5	<1.0	8.0	1.0	6.0	<1.0	11.0	<1.0
10.0	5.0	7.5	7.0	10.0	9.0	10.0	2.0	7.0	4.0	10.0	5.0	8.0	2.5	7.0	6.5
10.0	5.0	8.5	6.0	10.0	7.5	10.0	2.5	7.5	4.0	10.0	5.0	9.0	3.0	8.0	1.5
9.0	4.5	8.5	7.0	10.0	8.0	9.5	2.0	8.0	4.5	10.0	4.5	9.0	3.0	8.0	1.5
12.0	7.5	11.0	11.0	12.0	12.0	10.0	7.0	8.0	[illegible]	11.0	11.0	11.0	6.0	8.5	3.5
11.0	7.5	10.5	10.0	13.0	12.5	10.0	6.5	9.0	4.5	13.0	10.5	10.5	6.5	9.0	3.5
10.0	9.0	10.5	9.0	12.0	10.5	10.0	7.0	10.0	4.5	12.0	11.0	11.0	6.0	10.0	4.0
>40.0	<1.0	<40.0	3.5	>40.0	<1.0	22.0	<1.0	30.0	<1.0	>40.0	<1.0	25.0	<1.0	>40.0	<1.0
>40.0	<1.0	<40.0	2.5	>40.0	<1.0	>40.0	<1.0	28.0	<1.0	17.0	<1.0	>40.0	<1.0	23.0	<1.0
>40.0	<1.0	<40.0	1.0	30.0	<1.0	29.0	<1.0	25.0	<1.0	8.0	<1.0	25.0	<1.0	25.0	<1.0
19.5	<1.0	26.0	1.5	21.0	17.0	22.0	<1.0	28.0	<1.0	20.0	12.5	17.0	<1.0	26.0	<1.0
21.0	1.5	26.0	2.0	18.0	11.0	21.0	<1.0	27.0	<1.0	18.0	13.0	20.0	<1.0	26.0	<1.0
19.5	1.0	22.0	1.5	20.0	13.0	21.0	<1.0	21.0	<1.0	21.0	13.0	18.0	<1.0	17.0	<1.0
11.0	6.0	9.0	2.5	13.0	2.5	8.0	9.0	10.5	2.0	11.0	5.0	FLOWED FROM BOARDS	9.0	11.0	4.5
9.0	8.0	18.0	3.0	12.0	3.0	8.0	9.0	12.0	8.0	10.0	3.0		5.0	12.0	3.0
9.0	7.0	17.0	3.0	9.5	4.0	8.0	12.0	12.0	3.6	[illegible]	4.0		12.0	12.0	1.0
6.5	1.5	6.0	3.5	5.0	4.0	5.0	1.5	6.0	3.0	5.0	2.5	5.0	1.0	6.0	2.0
6.5	1.5	5.5	4.0	4.5	3.5	7.0	2.0	5.5	0.5	5.0	2.0	6.0	1.0	5.5	2.5
8.0	2.0	5.5	5.0	5.0	4.0	7.0	1.5	5.5	3.5	5.0	3.0	6.0	2.0	5.5	3.5
8.0	3.0	7.0	2.0	8.0	4.0	7.0	2.0	6.5	2.0	8.5	4.0	7.5	2.0	7.0	1.5
7.5	2.0	7.0	2.0	7.5	4.0	8.0	2.5	6.5	2.5	7.0	4.0	6.5	3.0	7.5	2.5
7.5	3.0	7.0	3.0	6.0	3.5	7.0	2.0	7.0	2.5	6.0	3.0	7.0	2.0	7.5	2.0

3

The materials that did not degrade were 17, 16 (UR's), 4, 25, and 26 (SR's). All other materials failed to maintain a measurable strength throughout the entire exposure procedure (Figures 2 through 5). With the exception of one material that was not on the QPL but was tested because it was known to revert, none of the materials that failed exhibited the classical softening, tacky or liquid condition which is associated with reversion. Instead, the typical failure mode was a gradual embrittlement and loss of elongation with the test material residue being granular and greatly darkened.

An analysis of the test data revealed two similar paradoxes which were unexplainable based on a comparison of the thermal test results or other test parameters. The results showed that all type ER failures occurred at 85°C, but none occurred at 105°C or 125°C. While no type UR failures occurred at 85°C, several occurred at 105°C and some occurred at 125°C.

The only reasonable explanation appeared to be incomplete cure as prescribed by the supplier. To verify this, a complete set of specimens of those materials that failed were prepared and cured more than one week at 85°C. These specimens were then subjected to 85°C and 97 percent for the ER materials and 105°C and 97 percent RH for the UR materials.

This retest provided no explanation for the above paradox since the results were the same as the original ones. In addition to consultation with Martin Marietta specialists, representatives of the material suppliers were contacted to obtain a viable explanation for the conflicts. There were no new explanations.

The fact that copper and other metals which commonly come in contact with the conformal coatings may react with them or otherwise affect their rate of degradation was considered. Since tin-lead is the most frequently used of these metals, several copper screen strips were prepared by hot dipping in a tin-lead bath. These solder coated screen strips were then used to make peel specimens in conjunction with ER material number 19 which was the most reversion susceptible of any of the materials. After humidity exposure at temperatures of 85°C, 105°C, and 125°C, the specimens provided the same results as when the material was coated on bare copper screen. The results of this test coupled with the fact that copper will almost invariably be encountered in coated assemblies prompted the continuation of testing with bare screening.

2. Solvent Resistance

The purpose of this investigation was to determine the susceptibility of the various materials to temporary or permanent degradation when subjected to solvent systems commonly used in printed wiring processes. These solvents come in contact with the coatings only after they are cured and then only for relatively brief periods; however, the times and method of testing were made more severe so that comparative resistance levels between materials could be determined.

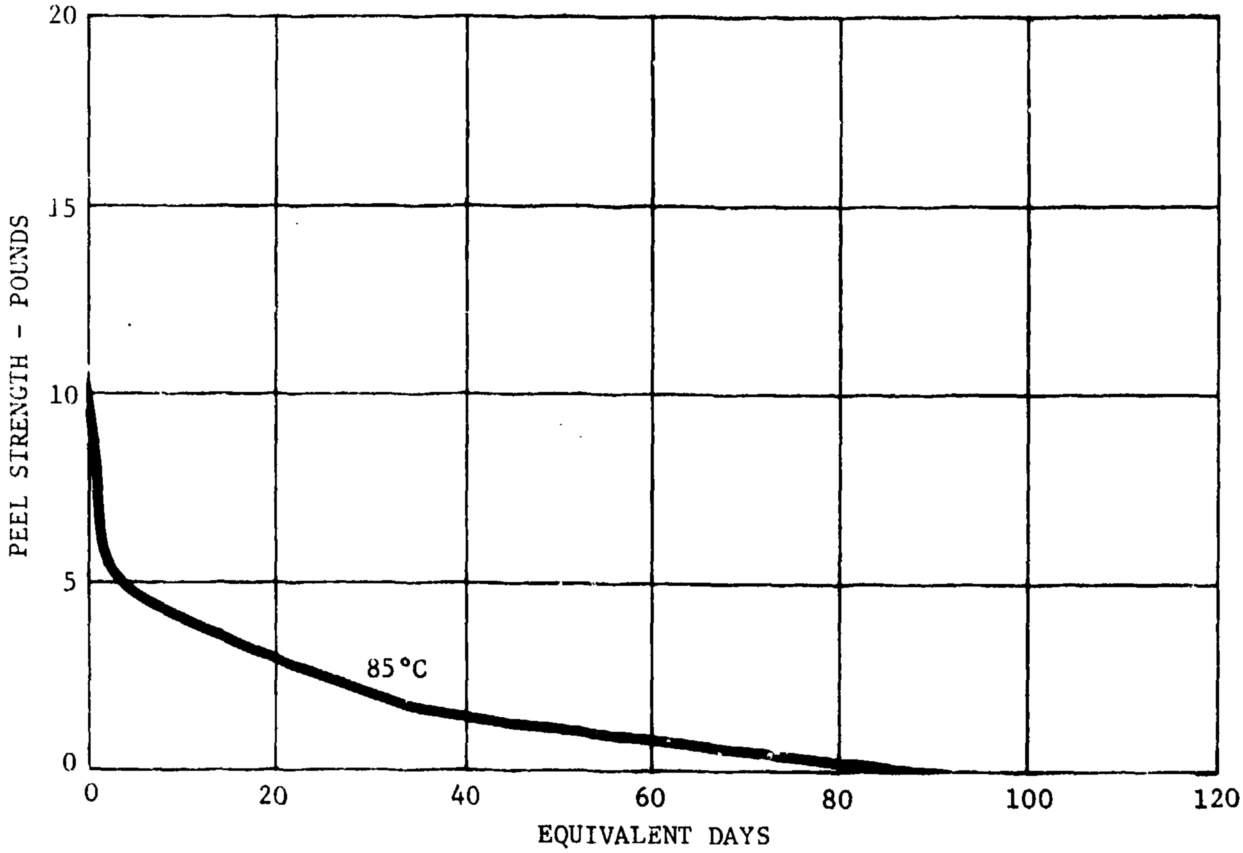

Figure 2 - Typical ER Material Degradation

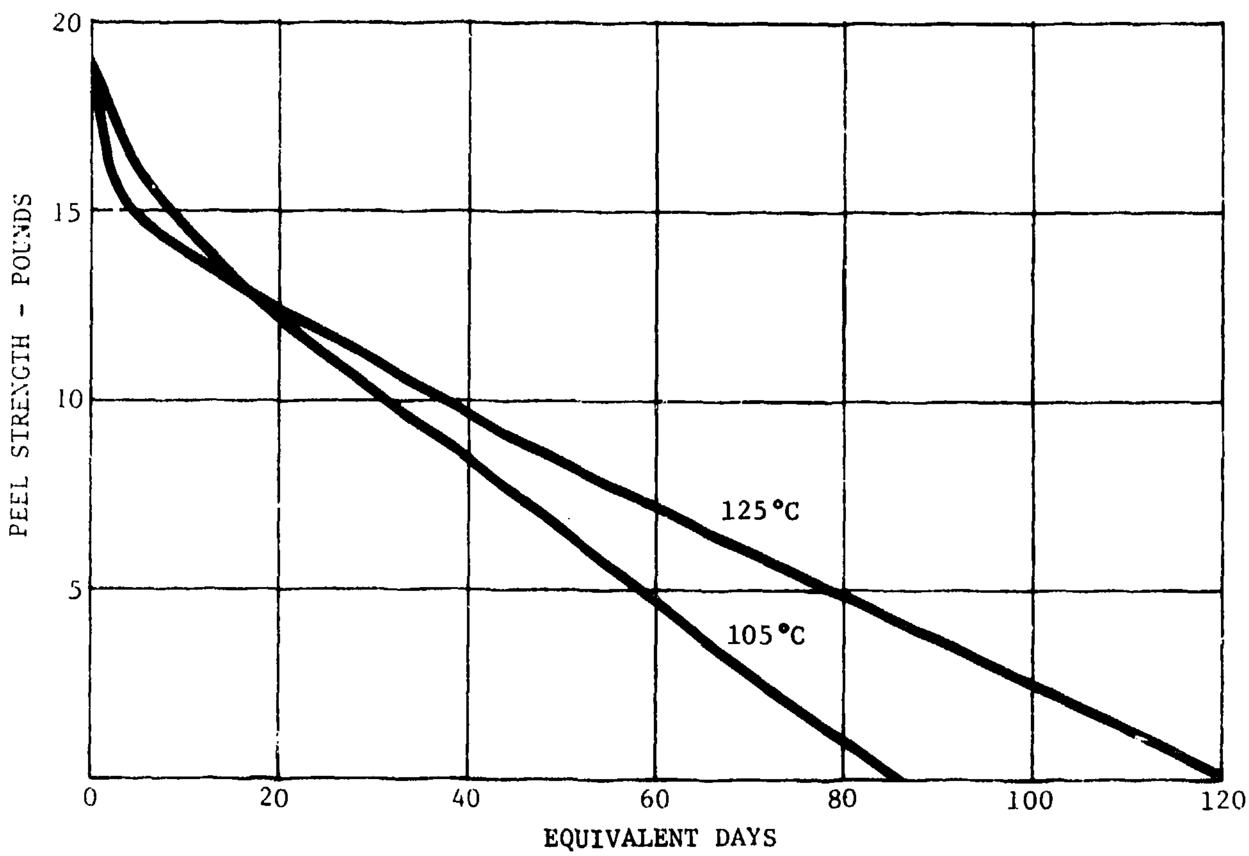

Figure 3 - Typical UR Long Term Degradation

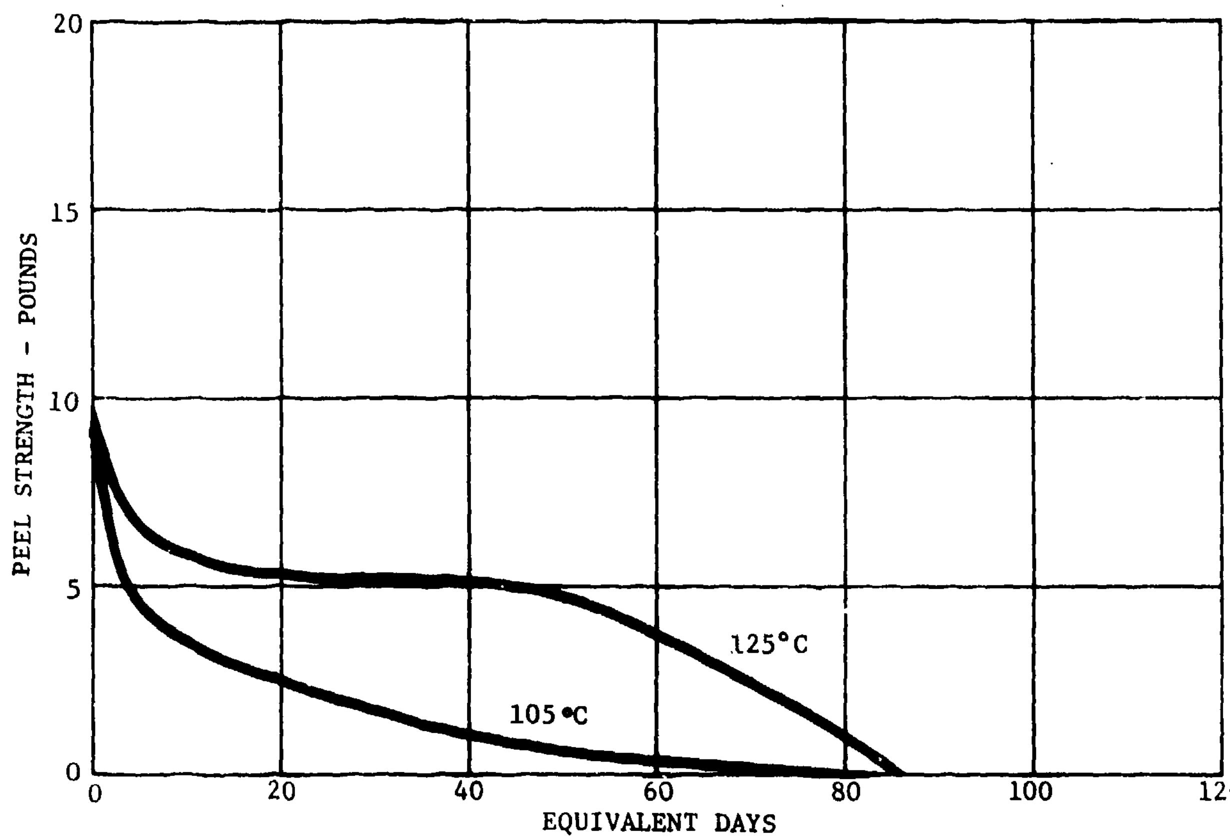

Figure 4 - Typical UR Medium Term Degradation

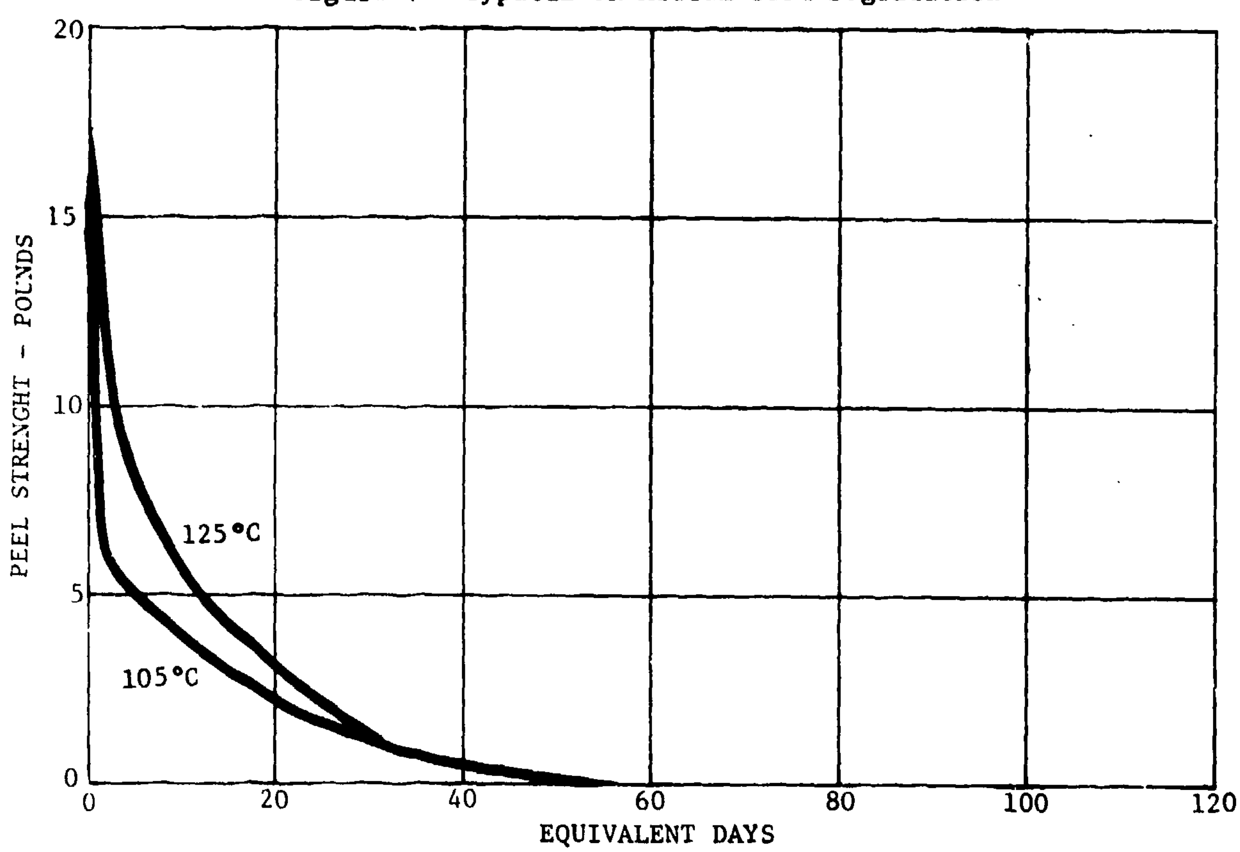

Figure 5 - Typical UR Short Term Degradation

The materials were applied to printed wiring board substrates in thicknesses ranging from 1 to 3 mils. The specimens were tested in accordance with method 215 of MIL-STD-202, soaked for an additional 55 minutes, and then brushed (Table II).

A separate set of specimens was weighed, soaked for 1 hour, weighed, dried for 1 hour at 180°F, and weighed again. This conditioning provided insight into the susceptibility of the material to absorption of the solvent as indicated by a gain in weight, and to the solubility of the materials as indicated by a weight loss after drying (Table III).

3. Buffer Materials

Before any temperature shock tests were initiated, a study was undertaken to determine the components most susceptible to cracking and the effect of positioning with respect to each other and to the board surface. The results of this investigation led to the selection of glass encased diodes and two sizes of glass encased resistors. It was also found that the probability of cracking was increased if the components were mounted in contact with the board surface. Based on reports of other members of the industry, a preliminary test program was performed to verify that the elevated temperature leg of the temperature shock test caused no stresses on the components; however, the results were not conclusive and therefore this leg of the cycle was retained.

The test specimens configuration used throughout the program conformed to the layout shown in Figure 6.

This combination provided isolated, close proximity, and abutting locations for the two resistor sizes and the diode.

While these data suggest the elimination of buffer materials in all applications when less than 6 mils of coating are used, field failures have been documented identifying cracked components when less than 3 mils of coating were used. As a result of a thorough analysis of all available data, it was concluded that no buffer material is needed in conjunction with type UR, SR, or AR materials in thicknesses less than 3 mils and with type ER materials coated on candidate components after successfully passing a thermal shock test without cracking.

If cracks occur as a result of the test, sleeving of polyvinylchloride conforming to MIL-I-631 TYF, Form U, Gr. C, CL. I, Cat. 1, polyolefin or polyvinylidene/fluoride conforming to MIL-I-23053 should be used as buffer materials.

The components were carefully cleaned with commercial solvent AP-20, isopropyl alcohol, and Freon TE. After the components were cleaned, they were dried in an oven at 150°F for 1 hour. Those components not mounted immediately were placed in a desiccator.

TABLE II

Solvents Process Effects

Test Material	Test Solvents: Alcohol Mineral Spirits			Chloroethane			TMC*		
	Not Affected	Softened	Lifts or Dissolves	Not Affected	Softened	Lifts or Dissolves	Not Affected	Softened	Lifts or Dissolves
1 UR	X			X					(3)
2 UR	X			X			X		
3 UR	X			X			X		
6 ER	X			X					(3)
7 ER	X					(55)			(2)
8 ER	X			X			X		
9 ER	X			X					(2)
10 ER	X			X					(3)
11 UR	X			X			X		
12 ER	X			X			X		
14 UR			(55)			(55)			(3)
15 UR	X			X				(55)	
17 UR	X					(3)			(3)
18 UR			(2)			(2)			(2)
19 ER	X					55			55

* Azeotrope of Trichlorofluoroethane and Methylene Chloride

( ) Time to React

TABLE III

Solvent Soak Resistance

Coating Material	Percent Change in Weight					
	After Soak			After Drying		
	Alcohol	Chlorethane	TMC	Alcohol	Chlorethane	TMC
3 UR	+1	+1	+1	0	0	0
15 UR	+1	+1	+1	0	0	-1
17 UR	0	+2	+2	0	0	0
2 UR	+1	0	+3	0	0	0
8 ER	+1	+1	+5	0	0	+1
11 UR	+1	+2	+4	0	0	+2
19 ER	0	+3	+5	0	0	-1
9 ER	+1	+2	0	0	0	X
1 UR	+1	+2	X	0	0	X
12 ER	0	+2	X	0	0	X
7 ER	0	+3	X	0	+1	X
6 ER	+2	+3	X	0	+1	X
14 UR	+2	+4	X	-4	-4	X
10 ER	+1	+21	X	0	-1	X
18 UR	+10	X	X	0	X	X

X = Dissolved

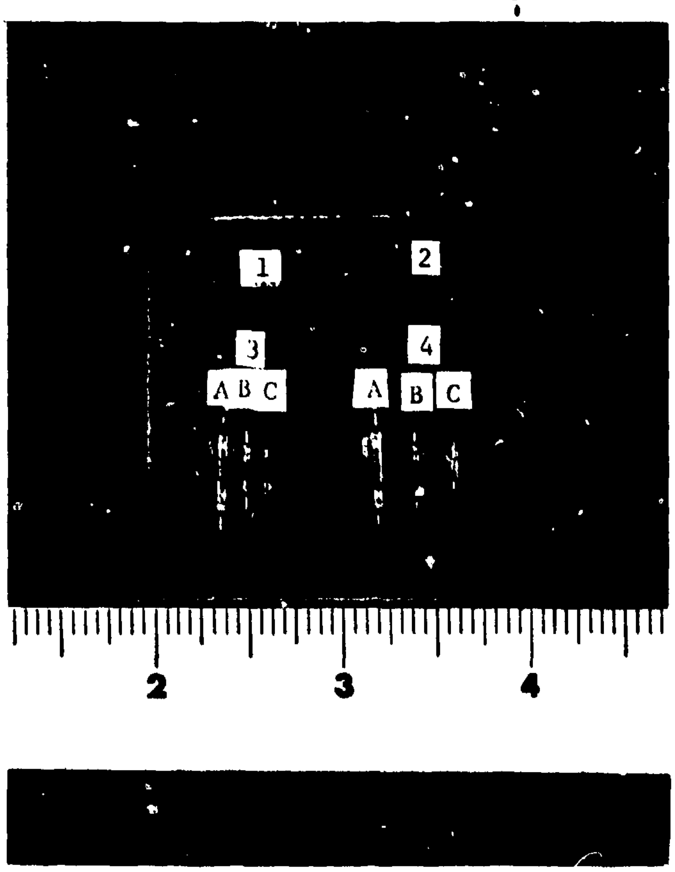

Figure 6 - Buffer Material Component Layout

The coatings were applied by spray where practical or by brushing to the selected thickness as measured on a flat surface of the material. The specimens were then subjected to a thermal shock test in accordance with MIL-STD-202, method 107, test conditions B, B-1, B-2, and B-3. The specimens were held at the extreme temperatures of -65°C and +125°C for 30 minutes with 2 minutes between temperature changes. The specimens were examined at the end of 5, 25, 50, and 100 cycles for defects.

The first set of specimens was coated to a thickness of 1 to 3 mils while the second set was coated to 5 to 7 mils thickness. Although no component cracks were detected in either of these cases, in the 6 mil thickness specimens, materials 9 and 14 exhibited cracks in the fillets around components 1 and 2.

Since no component cracks occurred in these tests (the first in thicknesses as specified in MIL-I-46058 and the second twice that thickness), it was agreed that substantially heavier thicknesses would be applied to a third set of specimens. This thickness was selected at 12 to 15 mils for testing ER and UR material. Material types AR and XY were not tested since they could not practically be applied in these thicknesses. Materials that remained highly flexible over the test temperature range were also excluded from this test.

This test sequence provided the results shown in Table IV.

TABLE IV

Thermal Cycling of 15 Mil Coatings

MATERIAL	SPECIMEN	THERMAL CYCLES			
		5	25	50	100
2 UR	1 2	(3),(1)-2,4B,4C (3),(1)-2,3A,4A, B,C	(3),(1)-2,4B,4C (3),(1)-2,3A,4A, B,C	(1)-2,4B,4C,(4),(5) (1)-3A,4A,B,C,(4), (5)	(1)-2,4A,4B,4C,(3),(5)-80% (1)-2,3A,4A,B,C(3),(5)-80%
3 UR	1 2	(2) (2)	(2) (2)	(2),(5) (2),(5)	(2),(5) (2),(5)
6 ER	1 2	(4) (4)	(4) (4)	(4) (4)	(4) (4)
7 ER	1 2	(4) (4)	(4) (4)	(3) (3)	(3) (3)
8 ER	1 2	(2) (2)	(2) (2)	(2) (2)	(2) (2)
9 ER	1 2	(2) (2),(1)-4C	(2) (2),(1)-4C	(1)-4B, (4) (1)-4C, (4)	(1)-4A, 4B, (4) (1)-4C, (4)
11 UR	1 2	(2),(1)-4C (2),(1)-4C	(2),(1)-4C (2),(1)-4C	(1)-4C, (4) (4)	(1)-4C,(4), (5) (4), (5)
12 ER	1 2	(2) (2)	(2) (2)	(4),(5) (4),(5)	(4),(5) (4),(5)
20 UR	1 2	(1)-3C (2)-4A	(1)-3C (2)-4A	(1)-3C, (2) (1)-3A,(2)	(1)-3C, (2) (1)-2, 3A, 4B, (2)

NOTES:

1. Parenthetical numbers refer to failure modes as follows:
   - (1) Components Cracked
   - (2) Coating cracked locally around components
   - (3) Coating cracked over entire board
   - (4) Coating cracked around leads only
   - (5) Coating delaminated from board
2. All other numbers and number-letter combinations refer to component type and placement as noted in Figure 6.

II. CONCLUSIONS

A. PHASE I - DEFECT ANALYSIS

1 The draft of the comprehensive Defect Analysis Guide has clearly established the feasibility of providing a military document that will significantly reduce repetition of common defects, thus reducing costs and delivery time.

2 The structuring of the guide enables expansion of existing classification as well as the addition of new ones.

B. PHASE II - CONFORMAL COATINGS

1. Reversion

1 With the exceptions of 2 UR and 3 SR materials, all materials exhibited significant degradation at one or two test temperatures.

2 Although some materials may appear to be acceptable on flat surfaces, they may be unacceptable because of brittleness and other mechanical deterioration well below original design requirements.

3 The failure mode of all materials except the one AR type was a progressive embrittlement in contrast to the more classical softening and liquification generally associated with reversion. In either case the materials have changed in characteristics well beyond those which they exhibited originally or for which the designer would have selected them.

4 UR materials failed under elevated temperature testing but not at 85°C, while the ER materials failed at the 85°C test temperature but not at the elevated temperatures. A rationale for this paradox has not been found.

5 The final test procedure developed and utilized to evaluate all materials provided reproducible results during test and retest cycles, used realistic coating thicknesses and materials, and required no specialized equipment.

2. Service Temperature

1 While most of the ER materials exhibited reduced mechanical properties after aging, all materials were stable enough to warrant their use up to 125°C.

2 The AR material softens and flows at 85°C and higher and the possibility exists that there are reduced thicknesses on vertical surfaces during elevated temperature exposures.

3. Buffer Materials

1 No evidence of component cracking was observed when coating thickness was less than 6 mils. Frequent and severe cracking occurred in thicknesses of 12 to 15 mils. There have been field failures of brittle components that had been coated with 3 mils or less of type ER material and subsequently cracked as a result of thermal shock exposure.

2 When the use of type ER materials is contemplated, preproduction thermal shock testing of representative assemblies is recommended.

4. Solvent Resistance

While most materials are resistant to permanent degradation by an alcohol-mineral spirits combination or chloroethane, several were attacked and permanently affected by TMC.

III. RECOMMENDATIONS

A. PHASE I - DEFECT ANALYSIS

The Defect Analysis Guide should be circulated to interested industry and military organizations for constructive comments.

B. PHASE II - CONFORMAL COATINGS

1. Reversion

   1 An investigation into the reason for the paradox specified in paragraph IIB1, 4 should be undertaken.

   2 Changes in color as a result of humidity exposure should not prevent distinguishing component color markings within the limits of MIL-STD-104.

2. Service Temperature

While many materials lost strength midway or at the end of the test period, the degradation was insignificant; therefore, except for AR materials, all could be recommended for use up to 125°C.

3. Buffer Materials

In thicknesses less than 3 mils, types SR, AR, and UR require no buffers. However, certain ER materials may crack brittle components when the assembly is subjected to thermal shock. Although recent assembly specifications require environmental testing of conformally coated assemblies, a thermal shock test, such as Method 107-B2 of MIL-STD-202, should be performed on test boards using the coating material, component types, configuration, and spacing representative of the production assembly. If the boards pass with no cracked coating or components, buffer materials need not be used on production boards.

4. Solvent Resistance

Type TMC solvent should be restricted from use on materials 1, 6, 7, 9, 10, 14, 17, and 18. Chloroethane should not be used on materials 17 or 18 and alcohol-mineral spirits on materials 18. A warning note to this effect should be noted in MIL-I-46058.

APPENDIX A

DEFECT ANALYSIS GUIDE

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PURPOSE

The purpose of this document is to provide a guide to the manufacturer of boards and the contracting agency that will identify various defects as specified in the several Military printed wiring specifications and standards, the phenomenology relating to their cause, and methods for correcting them.

It is intended to be a baseline for mutual understanding between the contractor and the contracting agency by providing insight into the cause of various defects and the corrective action necessary to prevent their recurrence. More timely deliveries, reduced costs, and greater reliability will result.

INTRODUCTION

The defects and rejection criteria specified in military specifications related to printed wiring material boards and assemblies represent a broad spectrum of problems which have arisen over many years of development, production, and service.

The incidence of these defects occurring range from random to frequent repetitions. Defects result in increased cost and loss of time in the fabrication and acceptance of boards and assemblies. Random defects can be expected in products supplied by even the most experienced and disciplined fabricator; however, this document is concerned with repeated defects in a supplier's product.

OUTLINE

This document is organized into three major sections. The first covers those materials that are used by the printed wiring board manufacturer to fabricate single-sided, double-sided, and multilayer printed wiring boards. The defects covered by this section are those that are the result of some action by this supplier.

The second section covers detail boards which have been completely processed, including drilling, etching, and plating but do not have components installed.

The third section is directed toward assemblies which consist of the detail board, components, and conformal coating. This section is not complete at this time due to the lack of an "assembly" requirements document which delineates defects and other reject criteria for assemblies.

The paragraph numbers are taken from MIL-P-55617A, MIL-G-55636A, MIL-P-13949E, MIL-STD-1495 basic, MIL-P-55110B Amendment 2, and MIL-P-55640A Amendment 1, and may change as the specifications are revised. However, the defect identification will not change as a result of specification amendments or revisions.

1.1 Materials

1.1 Prepreg

1.1.1 Defect-Resin flow too low

1.1.1.1 Definition - The resin which flows out of the prepreg when laminated is not sufficient to fill voids around multilayer conductors or may not provide sufficient flash when tested to the specified test procedure.

1.1.1.2 Reference Specification

MIL-G-55636 Paragraph 3.4.3

1.1.1.3 Description - When the prepreg is stacked and laminated, the resin liquifies and flows out of the stack to an extent determined by the laminating conditions and the viscosity of resin. If the resin gels too quickly, its flow will be reduced.

1.1.1.4 Cause - Low resin flow is the result of advanced "B" staging. This is caused by maintaining the prepreg for too long a period of time at a temperature above that recommended by the supplier.

1.1.1.5 Corrective Action - Upon receipt of the package check to see that it was properly handled and refrigerated during shipment. Store material under the conditions recommended by the supplier. Maintain a log of time and temperature when they are higher than those recommended. The higher the storage temperature, the more rapid will be the advancement of cure and reduction in flow.

1. Material

1.1 Prepreg

1.1.2 Defect - Volatile content too high

1.1.2.1 Definition - The materials in the prepreg which vaporize during the lamination process exceed requirements.

1.1.2.2 Reference Specification

MIL-G-55636 Paragraph 3.4.1

1.1.2.3 Description - In the process of coating the fabric with the resin it is almost completely driven off after the resin is applied. The retained solvent plus moisture will exceed specification requirements if not properly dried or stored.

1.1.2.4 Cause - A high volatile content measurement can be caused by moisture pickup due to breaking the wrapping seal on the package of prepreg before it has reached room temperature. This results in condensation of moisture on the prepreg which is cooler than the ambient air. Prepreg that has been properly unpacked but allowed to remain exposed to ambient humidity will approach a steady state balance with that humidity level and thus may absorb additional moisture, resulting in an unacceptable volatile content reading.

1.1.2.5 Corrective Action - Upon receipt of material, inspect the package to ensure that it is properly sealed. Before breaking the seal to inspect the prepreg, be certain that it has reached room temperature. Remove the required sample quantity and perform volatile content test as soon as possible.

1. Materials

1.2 Laminates

1.2.1 Defect - Dents

1.2.1.1 Definition - Depressions in the copper foil which do not significantly decrease the thickness of the copper foil.

1.2.1.2 Reference Specifications

MIL-P-13949 Paragraph 3.3.3

MIL-P-55617 Paragraph 3.2.2

1.2.1.3 Description - When viewed at a decreasing angle approaching the plane of the edge of the board, the dent can be observed as a depression in the surface of the copper cladding. The dent when formed during the laminating process will generally not exhibit scratches or external damage to the copper surface; however, when they occur after receipt of the laminate, the copper frequently shows external signs of abuse.

1.2.1.4 Cause - The cause of dents after receipt of the laminate can be attributed to handling procedures. The dent is caused by concentrated force applied to a localized area and can be the result of foreign bodies being lodged between adjacent laminates during handling and storage, or by tools or other objects being dropped or otherwise impacted against the surface.

1.2.1.5 Corrective Action - Each laminate should be handled and treated as a separate item. That is, each should be removed from the package, inspected, and placed on a flat surface or carrier. Prior to placing the next sheet on top, the surface of the previous laminate should be checked for foreign materials. During transportation from one area to the next, the laminates should be protected from impact against benches, equipment, and other objects.

1. Materials

1.2 Laminates

1.2.2 Defect - Scratches

1.2.2.1 Definition

1.2.2.2 Reference Specifications

MIL-P-13949 Parag.aph 3.3.4

MIL-P-55617 Paragraph 3.2.3

1.2.2.3 Description - The copper surface has been partially cut or displaced by a sharp object. Scratches may be random and individual or may be lc.alized in one area. A scratch does not penetrate the entire thickness of the copper.

1.2.2.4 Cause - Scratches most commonly occur as a result of poor handling after inspection. If care is not taken to ensure that foreign particles or objects are not removed from between laminates during storage or transfer, scratches will occur. Placement of laminates on dirty work surfaces, placing sharp tools or other objects on the laminate, or dragging against benches and equipment will cause scratches.

1.2.2.5 Corrective Action - Inspect laminates for foreign objects prior to stacking together. Transfer laminates in protective containers. Inspect work surfaces for foreign objects and place tools on work surfaces or tool racks away from the laminate.

1. Materials

1.2 Laminates

1.2.3 Defect - Bow (warping)

1.2.3.1 Definition - the deviation from flatness of a board characterized by a roughly cylindrical or spherical curvature such that if the board is rectangular, its corners are in the same plane as the major surfaces of the board.

1.2.3.2 Reference Specifications

MIL-P-13949 Paragraph 3.4

1.2.3.3 Description - When placed on a plane surface, the laminate will curve away from it but the corners and generally two edges will be in contact with the surface. Occasionally, only the corners will contact the surface.

1.2.3.4 Cause - Bow in a single side board is a natural reaction to laminating two materials, copper and the laminate, with different coefficients of expansion together. At laminating temperature the materials are of equal size; however, as the composite cures, the laminate shrinks more than the copper does and the finished laminate is bowed at room temperature. Mechanical straightening can be accomplished by bowing it in the opposite direction, thus stretching the copper. Other causes of bowing are improper stacking such as not fully supporting a vertically stacked laminate so that it can slide or slump into a curved shape or not completely supporting a horizontally stacked laminate, thus allowing it to droop over the ends of the shelf.

Detail boards - When the amount of etched copper varies greatly from one side to the other or between the layers of a multilayer board, the completed board will be bowed or twisted. Bow and twist will also result if after the board has been subjected to heat such as wave soldering or laminating, it is flexed or placed on an uneven surface before it is cooled to room temperature.

1.2.3.5 Corrective Action - Laminates should be handled so that they are not forcibly bent or twisted. They should be placed on shelves only if they are supported across the entire surface and on edge only if they are restrained from bowing.

Detail boards - Two sided boards should be designed such that the remaining copper or two sided boards are approximately the same on both sides. If ground or voltage planes are required on multilayer boards they should be placed as near the center plane of the board as possible. After exposure to heat the boards should be cooled in a flat surface or in a restraining fixture.

1. Materials

1.2 Laminates

1.2.4 Defect - Twist

1.2.4.1 Definition - Bending or curving distortion from a true or plane surface in a direction parallel to a diagonal between two opposite corners of the sheet.

1.2.4.2 Reference Specifications

MIL-P-13949 Paragraph 3.4

1.2.4.3 Description - When placed on a plane surface, the laminate will contact it at only two diagonally opposite corners.

1.2.4.4 Cause - Twist is generally caused when the laminate is picked up by one corner or rested on one corner with pressure being applied to an opposite corner.

1.2.4.5 Corrective Action - Laminates should always be picked up along one edge and transported in a manner so that the laminate is vertical and fully supported on the bottom edge. Laminates should be stored on flat surfaces or should be stored in vertical racks which maintain the laminates in a vertical position.

1. Material

1.2 Laminates

1.2.5 Defect - Chipping

1.2.5.1 Definition - Surface imperfections in the form of a cut or gouge wherein small fragments of surface material are displaced or removed.

1.2.5.2 Reference Specifications

MIL-P-55617 Paragraph 3.2.3

1.2.5.3 Description - Chipping occurs on the unclad surface of laminates and is characterized by voids in laminate surface.

1.2.5.4 Cause - Chipping is caused when the resin surface of the laminate is impacted by a sharp object. These can include, tools, other laminates, equipment, and benches.

1.2.5.5 Corrective Action - Handle each laminate individually and store them in protective racks, transport the laminates in protective carriers, and use care in handling tools when preparing the laminate for fabrication.

2. Detail Boards

2.1 Board Materials

2.1.1 Defect - Measling

2.1.1.1 Definition - Measling is an internal condition occurring in the laminated base material in which the glass fibers are separated from the resin. This condition exists in the form of discrete white spots or crosses evident at individual and scattered weave intersections. It is usually made visible by mechanical or thermal stresses or both.

2.1.1.2 Reference Specifications

MIL-P-55640 Paragraph 3.10, 3.12, 3.15 3.19

MIL-P-13949 Paragraph 3.6, 3.7

MIL-P-55617 Paragraph 3.2.5

2.1.1.3 Description - A measle occurs when the resin-to-glass interfacial bond strength is exceeded. The primary sources of the stresses which are sufficient to overcome this bond are volatiles entrapped in the composite. These may be unreleased volatiles from the prepreg or those (such as moisture) accumulated during storage and processing. These volatiles accumulate in interfacial void areas. When the composite is exposed to thermal shock (such as soldering), the volatiles expand violently and cause extensive fracturing of the resin and debonding of the resin-to-glass interface within and immediately surrounding the intersection of warp and fill yarns.

2.1.1.4 Causes - The following delineates the major causes of measling:

1 Laminating - A prepreg volatile content in excess of 0.75 percent will enhance the possibility for measling of the laminated board during thermal shock.

2 Handling and Fabrication - Excessive stresses imposed on the board during handling and fabrication will cause the glass-to-resin bond to become weakened. While this weakening does not manifest itself immediately as measles, measling will occur under thermal shock. Typical stress conditions include impacting during installation of terminals, shearing, excessive drill speeds, and severe flexing of the board.

3 Moisture - Storage in areas of high humidity will allow sufficient moisture to absorb so that when the board is subjected to thermal shock, such as soldering, the moisture expands rapidly, the glass-to-resin interfacial bond is broken, and measling results.

2.1.1.5 Corrective Action - Perform the following procedures to prevent recurrence of the measling defects:

1 Obtain material that has silane treatment on the glass. This treatment is highly resistant to moisture and therefore greatly reduces measling caused by high moisture content.

2 Dry off retained moisture by baking at 100°C for one hour. Maintain dry condition until after soldering or other thermal shock.

3 Avoid rapid changes in temperature.

4 Review handling and fabrication procedures to determine the presence of conditions which cause mechanical stressing of the board. A common condition is impacting on the board during the insertion of terminals, shearing and drilling with dull tools, or drilling at too high rates of speed. Obtain drill sharpening and speed instructions from material suppliers. Adjust terminal insertion tools so that the board is not compressed during insertion.

5 Thicker materials are generally more resistant to measling than thin materials and will provide an added safety margin against measling.

6 Increase the frequency of solder resistance testing during acceptance inspection if measling occurs on a cyclical or seasonal basis.

2. Detail Board

2.1 Board Material

2.1.2 Defect - Cracks, Board Surface

2.1.2.1 Definition - Separation of the surface layer of resin occurring as fissures which may or may not penetrate entirely through the resin layer to the glass fabric.

2.1.2.2 Reference Specifications

MIL-P-55110 Defect 12A13, Paragraph 4.9.1.1

MIL-P-55640 Defect 12A13, Paragraph 4.6.1.2.2

2.1.2.3 Description - The surface of the laminate has a layer of resin which is normally continuous and completely covers the outer layers of glass fabric. Cracks that may occur in this surface layer will exhibit a non-uniform pattern which is not dependent on the fabric pattern. The depth of the cracks may vary from a few microinches to complete penetration of the resin layer into the glass fabric.

2.1.2.4 Cause - The primary cause of surface resin coat cracking is mechanical stressing. These stresses may come from bending the board, impacting the surface with a blunt instrument, or clamping.

2.1.2.5 Corrective Action - Eliminate practices that cause mechanical stressing of the board. One of the practices frequently encountered is manual straightening of a board which had become warped during a previous operation. Wave solder fixture clamps should be "stopped" short of contacting the board surface or should be coated with a soft plastic or elastomer.

2. Detail Boards

2.1 Board Material

2.1.3 Defect - Bulges, board surface

2.1.3.1 Definition - Swelling and separation between any of the layers of the base laminate or between the laminate and the metal cladding.

2.1.3.2 Reference Specifications

MIL-P-55110 Defect 12A13, Paragraph 4.9.1.1

MIL-P-55640 Defect 12A13, Paragraph 4.6.1.2.2

2.1.3.3 Description - A separation of the copper from the surface of the board or between the inner layers of the base laminate. The separation manifests itself as a locally raised area on the board or copper foil.

2.1.3.4 Cause - The basic cause of this defect is a poor or weak bond between the foil and the board or the layers of the base laminate. These poorly bonded areas are not apparent in the as-received condition but when the board is subjected to thermal shock conditions, expansion forces of the board materials and moisture entrapped in the board combine to force the layers apart leaving a raised area.

2.1.3.5 Corrective Action - Increase acceptance inspection solder shock testing on all material received. Keep moisture content in board as low as possible by storing in humidity less than 50 percent and baking prior to wave soldering or solder reflow operations. See also Measling (paragraph 2.1.1).

2. Detail Boards

2.1 Board Material

2.1.4 Defect - Removal of Board Material, unspecified

2.1.4.1 Definition - Any visible removal of board material other than as specified on the drawing.

2.1.4.2 Reference Specifications

MIL-P-55110 Defect 12A19 Paragraph 4.9.1.1

MIL-P-55640 Defect 12A14 Paragraph 4.6.1.2.2

MIL-P-50884 Defect 104 Paragraph 4.7.1.1

2.1.4.3 Description - Board material has been removed leaving holes or indentations in the base laminate.

2.1.4.4 Cause - Board material can be removed by mechanical or chemical means. Mechanical removal is a result of drilling, sawing, milling, or shearing improperly or in the wrong places as specified on the drawing. Severe abuse such as dropping tools on the board, dropping the board on an edge, or striking against unyielding surfaces will also cause removal of board material. Chemical removal may be caused by strong solvents such as acetone or acids such as sulfuric.

2.1.4.5 Corrective Action - Survey handling procedures to ensure that handling and transportation of details are performed using protective carriers. Improperly drilled, punched, sheared, or milled areas are caused by human error and can be corrected by providing templates to act as overlays over the blank board prior to carrying out the above procedures. Automatic tape or computerized equipment will eliminate many of the problems.

2. Detail Boards

2.1 Board Material

2.1.5 Defect - Delamination

2.1.5.1 Definition - A separation between any of the layers of the base laminate and B-stage material or between the laminate and the metal cladding originating from or extending to the edges of a hole or edge of the board.

2.1.5.2 Reference Specifications

MIL-P-55110 Defect 12A23 Paragraph 4.9.1.1

MIL-P-55640 Defect 12A23 Paragraph 4.6.1.2.2, 3.10, 3.12, 3.15, 3.19, 3.20

MIL-P-50834 Defect 114 Paragraph 3.6, 3.7

MIL-P-13949

MIL-P-55424 Paragraph 3.9, 3.10, 3.11, 3.12, 3.13, 3.14

2.1.5.3 Description - Delamination is a cohesive failure of the resin between the layers of glass fabric in the laminate. It normally manifests itself as a circular, light colored area within the board.

2.1.5.4 Cause - Delamination is normally the result of mechanical stressing followed by thermal stress. Unlike a blister which is the result of a poor layer to layer bond, delamination is the fracturing or the degradation of a satisfactory bond which is forcibly separated by thermal stresses. These stresses may be the result of expansion differences between layers or the vaporization of moisture which forces the weakened bond apart.

2.1.5.5 Corrective Action - Remove or eliminate any operation that imposes localized mechanical compressive stresses on the laminate. Maintain board in an environment where the relative humidity is less than 50 percent and bake boards prior to thermal shock such as solder plate reflow or wave soldering. See also Measling (paragraph 2.1.1).

2. Detail Board

2.1 Board Material

2.1.6 Defect - Bow (warping)

2.1.6.1 Definition - The deviation from flatness of a board characterized by a roughly cylindrical or spherical curvature such that if the board is rectangular, its corners or edges are in the same plane as the major surfaces of the board.

2.1.6.2 Reference Specifications

MIL-P-55110 Defect 12A15 Paragraph 4.9.1.1

MIL-P-55640 Defect 12A15 Paragraph 4.6.1.2.2

MIL-P-13949 Paragraph 3.4

MIL-P-27538 Paragraph 3.3

MIL-P-55424 Paragraph 3.6

2.1.6.3 Description - When placed on a flat surface, all four corners will touch the surface and generally two parallel edges will also touch the surface.

2.1.6.4 Cause - Bow and twist are caused by unbalanced circuit patterns on opposite sides of two sided board. Since the laminate and copper have different coefficients of thermal expansion, stresses develop in the laminate as it is cooled to room temperature. Etching away copper to form a circuit pattern relieves some of these stresses and if the amount and location on each side differs extensively, warping or bowing will result.

ubjected to heat such as during wave soldering or reflowing, type GE and GF boards become pliable and unless handled carefully or cooled in a supporting frame or carrier, they will yield to slight pressure and take a permanent set when cooled.

2.1.6.5 Corrective Action - Where possible provide as closely a balanced pattern on both sides of printed wiring boards. Cross hatch ground and voltage planes. Support boards on all edges during thermal exposure such as reflowing or wave soldering. Leave boards in holders until they are cooled to room temperature. Cool multilayer boards under pressure until the board reaches 150°F or less.

2. Detail Boards

2.1 Board Material

2.1.7 Defect - Crazing

2.1.7.1 Definition - Crazing is an internal condition occurring in the laminated base material in the form of connected white spots or crosses (measling). It is usually made visible by mechanical or thermal stresses or both. This connected measling forms continuous paths which may carry moisture or electric current or both.

2.1.7.2 Reference Specification

MIL-P-55640 Paragraph 3.10, 3.12, 3.15

2.1.7.3 Description - Crazing is seen as irregular cracks or striations in the outer resin layer. These cracks may only penetrate the surface of the layer or may propagate through to the glass fabric layer.

2.1.7.4 Cause - Crazing is caused by thermal stresses from wave soldering, cleaning, drying, or testing or from mechanical abuse such as flexing the board or impacting the board surface with tools or other hard objects.

2.1.7.5 Corrective Action - Handle all boards carefully to prevent excessive stress to the board. Place boards in protective carriers that provide support, prevent flexing, and ensure that sharp objects cannot come in contact with the board surface.

2. Detail Board

2.1 Board Material

2.1.8 Defect - Drag

2.1.8.1 Definition - A distortion of the conductor or base edge caused by improper cutting.

2.1.8.2 Reference Specification

MIL-P-55110 Paragraph 3.5.2

2.1.8.3 Description - Drag is characterized by the transfer of conductor material from the surface of its layer to the edge of the board and appears as a smear of metal somewhat wider than the conductor thickness.

2.1.8.4 Cause - This condition is caused by cutting tools which are not properly sharpened or are improperly utilized in the board fabrication processes. An improperly sharpened or a set shear will cause serious drag of the conductor but may adequately shear the more brittle board material. Drag arising from the use of routers and drills results from dull tools or improper feed or speed.

2.1.8.5 Corrective Action - Inspect cutting edges of shears, routers and punches. Dress and grind nicks or dull edges to the correct angle. Analyze feed rates and speed of routers and drills to ensure their proper selection for the operation and material involved.

2. Detail Board

2.1 Board Material

2.1.9 Defect - Blistering

2.1.9.1 Definition - Swelling and separation between any of the layers of the base laminate or between the laminate and the metal cladding.

2.1.9.2 Reference Specifications

MIL-P-55640 Paragraphs 3.10, 3.12, 3.15, 3.19

MIL-P-55617 Paragraph 3.2.5, 3.4

MIL-P-13949 Paragraph 3.6, 3.7, 3.18

MIL-P-55424 Paragraph 3.9, 3.10, 3.11, 3.12, 3.13, 3.14

2.1.9.3 Description - Blistering is the failure of the laminating resin between the layers of glass fabric or the outer layer of fabric and the conductor. It results when thermally induced stresses exceed the cohesive strength of the resin. If moisture or other volatiles are present, the pressure will cause distinctly arched irregularities in the board thickness. Blisters are visible as light patches with smoothly radiused edges.

2.1.9.4 Cause - Blistering occurs when the interlaminar bond strength of the laminate is exceeded by the pressure exerted when volatiles such as moisture are released during thermal exposure. A board that has been locally stressed will blister when exposed to thermal shock.

2.1.9.5 Corrective Action - Dry boards prior to thermal shock exposure such as hot oil, wave soldering, or reflow operations. To improve blisters between ground or voltage planes and the bond plies of multilayer boards, treat the drum side with supplementary oxide treatments or use pretreated copper. Review multilayer laminating procedures to ensure that bonding layers are completely cured. Protect boards from impact by tools or equipment.

2. Detail Board

2.2 Circuit

2.2.1 Defect - Cuts or scratches; conductor

2.2.1.1 Definition - Cuts or scratches completely across a conductor or more than 1/2 inch along a conductor. When this defect can be considered as reduction in area of conductor, evaluate in accordance with defect 12A8 or 12B8, as applicable.

2.2.1.2 Reference Specifications

MIL-P-55110 Defect 12B18 Paragraph 4.9.1.1, 3.5

MIL-P-55640 Defect 12B18 Paragraph 4.6.1.2.2, 3.6.7

MIL-P-50884 Paragraph 3.5

2.2.1.3 Description - Cuts and scratches are essentially the same defect except that cuts penetrate through the conductor for a portion or entire length of the cut. Scratches are normally covered by solder during the wave solder process while the solder may not bridge a cut.

2.2.1.4 Causes - Cuts and scratches result from improper handling of the detail board. Scratches generally occur from boards coming in contact with each other or being placed on surfaces with harsh foreign material on them. Placing tools or fixtures on boards will also cause scratches. Cuts may also be caused during attempts to trim superfluous conductor or bridging.

2.2.1.5 Corrective Action - Transport detail boards in protective carriers. Separate detail boards with kraft paper or plastic film when stacked. Follow corrective action for superfluous conductor to avoid the need to trim the conductor.

2. Detail Board

2.2 Circuit

2.2.2 Defect - Edge Roughness

2.2.2.1 Definition - Uneveness of the periphery of the conductor greater than 0.005 inch from peak to valley.

2.2.2.2 Reference Specifications

MIL-P-55110 Defect 12B20 Paragraph 4.9.1.1, 3.5

MIL-P-55640 Defect 12B20 Paragraph 4.6.1.2.2, 3.6.7

MIL-P-50884 Defect 108 Paragraph 4.7.1.1, 3.5

2.2.2.3 Description

The edge of the conductor will appear as an uneven saw tooth varying from less than 0.001 inch to sometimes greater than 0.010 inch. The irregularity may be smooth (when caused by plating) or rough when resulting from etching or undercutting.

2.2.2.4 Cause - Edge roughness results from a defective master pattern, too rapid etching, or poorly plated resist plating. Highly active etchants with poor circulation will cause uneven and roughly etched conductors. Defective or improperly exposed resist will result in rough edges. When resist plating is panel plated using current densities which are too high, a rough edge will result on the plating. This edge will be reproduced or aggravated during etching.

2.2.2.5 Corrective Action - Inspect master patterns for quality and foreign matter. Review plating processes to ensure that electrolyte control, current densities, and agitation are within acceptable limits.

2. Detail Boards

2.2 Circuit

2.2.3 Defect - Width Reduction of Conductors

2.2.3.1 Definition - Any reduction of effective design width below that specified on master drawing. Reduction of 20 to 35 percent is a minor defect (12B8), and reduction greater than 35 percent is a major defect (12A8).

2.2.3.2 Reference Specifications

MIL-P-55110 Defects 12A8 or 12B8 Paragraph 4.9.1.1, 3.5.1

MIL-P-55640 Defects 12A8 or 12B8 Paragraph 4.6.1.2.2, 3.6.8

MIL-P-50884 Paragraph 3.5

2.2.3.3 Description

Reduction may occur in a section of a given conductor, in several adjacent conductors in a board area, or in all conductors on a board.

2.2.3.4 Cause - Reduced line width will occur when the master pattern has opaque foreign matter (pattern plating) or emulsion removed (panel plating) so that the resist no longer prevents etching of the intended conductor or does not allow the prescribed width of plating resist to be applied. Reduced line width will occur as a result of over etching. It will also occur if during touchup of resist defects, the touchup ink is inadvertently applied over the edge of a conductor.

2.2.3.5 Corrective Action - Carefully inspect master pattern for defects and foreign material. If reduced area is nonrepetitive, the cause was probably due to resist touchup or foreign matter. If reduction occurs in all conductors or in a broad area of a panel, check etching conditions.

2. Detail Board

2.2 Circuit

2.2.4 Defect - Register, Misaligned

2.2.4.1 Definition - The relative position of one or more printed wiring patterns, or portions thereof, with respect to their desired locations on the base material.

2.2.4.2 Reference Specification

MIL-P-50884 Defect 118 Paragraph 4.7.1.1

MIL-P-55640 Paragraph 3.6.1.3

2.2.4.3 Description

In two sided boards the misregistration will generally be uniform over the entire board surface and normally results from misalignment of the master pattern when exposing the resist. In multilayer boards the misregistration may be uniform as in the two sided board or it may be in localized areas in different layers in the board. If it is localized it generally is a result of dimensional instability of the thin laminate layer.

2.2.4.4 Cause - When the master patterns for opposing layers of two sided boards are located in the prescribed position on the board, misregistration between the layers will result when the circuit is etched; layer to layer misregistration will also occur in multilayer boards when tooling index holes in individual layers are not properly placed. Dimensional instability in the laminates will also cause misregistration in multilayer applications since the individual laminates will shrink or expand to differing extents.

2.2.4.5 Corrective Action - Inspect all art work for properly positioned hole and conductor patterns. Check tooling holes in master pattern and laminate to verify their proper location. Dimensional stability in thin laminate layers in multilayer boards will effect the layer to layer registration in the composite board; therefore, review the acceptance inspection procedures followed when receiving thin laminates. Follow MIL-P-55617 acceptance testing.

2. Detail Boards

2.2 Circuit

2.2.5 Defect - Spacing of conductors, less than minimum

2.2.5.1 Definition - The distance between closest edges of two adjacent conductors.

2.2.5.2 Reference Specifications

MIL-P-55110 Defect 12A11 Paragraph 4.9.1.1

MIL-P-55640 Defect 12A11 Paragraph 4.6.1.2.2, 3.5.2

2.2.5.3 Description

The spacing as set forth with master drawing has not been maintained on the etched circuit. The reduction may occur for the entire length of two parallel or skew conductors or may appear as discrete protrusions on one conductor.

2.2.5.4 Cause - Spacing discrepancy results from superfluous conductor (spacing too narrow) or reduced width (spacing too wide).

2.2.5.6 Corrective Action - See Width reduction of conductors (paragraph 2.2.3) or Superfluous conductor (paragraph 2.2.7).

2. Detail Boards

2.2 Circuit

2.2.6 Defect - Annular Ring, insufficient

2.2.6.1 Definition - The circular strip of conductive material completely surrounding a hole is less than master pattern allows.

2.2.6.2 Reference Specifications

MIL-P-55110 Defect 12A17 Paragraph 4.9.1.1

MIL-P-55640 Defect 12A17 Paragraph 4.6.1.2.2, 3.6.1.1

MIL-P-50884 Defect 116 Paragraph 4.7.1.1, 3.15.1, 3.15.2

2.2.6.3 Description

The functional conductor surrounding the hole is reduced in width due to the center of the hole not being coaxial with the center of the terminal area. The annular ring may vary from a full as-designed width at all points down to a point where the circumference of the hole coincides with the circumference of the terminal area at one point. Beyond this "break-out" occurs.

2.2.6.4 Cause - There are three general causes for insufficient annular ring. The most common cause is misregistration of the terminal area. The second cause is an improperly placed hole, and the third is overetching.

2.2.6.5 Corrective Action - Check tooling to ensure that the master pattern is accurately positioned with respect to the holes. In the case of thin laminates used to fabricate multilayer boards, misregistration may also result from laminate dimensional changes after etching. Review drilling procedures and inspect drill tapes if it is suspected that the hole was misplaced. When the reduced annular ring is caused by overetching, review etching process parameters and controls. Excessive time, temperature, and etchant concentration or poor agitation may be the cause.

2. Detail Boards

2.2 Circuit

2.2.7 Defect - Superfluous Conductor

2.2.7.1 Definition - A useless, unnecessary conductor, potential cause of short. Clearance less than that specified in master drawing for electric spacing.

2.2.7.2 Reference Specifications

MIL-P-55110 Defect 12A6 Paragraph 4.9.1.1

MIL-P-55640 Defect 12A6 Paragraph 4.6.1.2.2

2.2.7.3 Description

A distinct change in the width of the conductor which reduces the spacing between the conductor and adjacent circuit details. This excess conductor may be a spike or smooth irregularity in the conductor edge profile.

2.2.7.4 Cause - Superfluous conductor results when etchant is prevented from removing unwanted copper. The material preventing this etching can be photo resist, foreign material, or resist plating. Unwanted photo resist may remain if master pattern contained opaque foreign matter with panel plating or a scratch in the negative with pattern plating. It may also remain if an organic or an etchant resistant metallic contaminant remained over the conductor edge.

2.2.7.5 Corrective Action - Inspect master pattern for scratches or foreign matter. Check handling practices to ensure that persistent particles are not becoming impressed on the unetched panel; inspect incoming raw material to ensure that excessive inclusions are not present on foil.

2. Detail Boards

2.2 Circuit

2.2.8 Defect - Peeling and lifting of conductor

2.2.8.1 Definition - Any looseness of conductor to board or any conductor length, any peeling of conductor (defect most prevalent at terminals and at ends of conductor contacts).

2.2.8.2 Reference Specification

MIL-P-55110 Defect 12A1 Paragraph 4.9.1.1, 3.6

MIL-P-55640 Defect 12A1 Paragraph 4.6.1.2.2

MIL-P-50884 Defect 112 Paragraph 4.7.1.1

2.2.8.3 Description

Lifting generally occurs around the edges of terminal areas. When looking down on the lifted conductor, it may not be detectable; however, when viewed at an oblique angle, the separation of the copper from the board will be visible.

2.2.8.4 Cause - Undercutting of the conductor by etchant is the primary cause of reduced peel strength. In addition, concentrated thermal exposure such as caused by a soldering iron will also cause reduced bond.

2.2.8.5 Corrective Action - Review etching procedures. Check the finish applied to the drum side of the copper to determine if it is too readily attached by the etchant. Check all soldering procedures to ensure that soldering times are not exceeding a normal 5 to 10 second dwell.

2. Detail Boards

2.2 Circuits

2.2.9 Defect - Undercutting

2.2.9.1 Definition - The reduction of the cross section of a metal-foil conductor caused by the etchant removing metal from under the edge of the resist or plating.

2.2.9.2 Reference Specification

MIL-P-55640 Paragraph 3.6.5

2.2.9.3 Description

As the etchant removes the unwanted copper from the surface of the board, it is also removing copper laterally under the resist. As etching progresses to the board surface, the removal of the copper under the resist has progressed an amount approximately equal to the copper thickness. Thus, the resist will be left hanging over the etched conductor. If the board remains in the etchant beyond the time necessary to take away the unneeded copper, the lateral etching will continue and undercutting will continue, thus reducing the conductor width and increasing the amount of overhanging resist.

2.2.9.4 Cause - Conductor overhang is the result of overetching. The overhanging conductor is the resist plating which remains after the conductor has been etched away beneath it.

2.2.9.5 Corrective Action - Review etching procedures, time, temperature, aeration, agitation, and etchant concentration to be sure they are correctly balanced.

2. Detail Boards

2.3 Plating

2.3.1 Defect - Insufficient Plating

2.3.1.1 Definition - Absence of plating, voids, or thin plating.

2.3.1.2 Reference Specification

MIL-P-55110 Defect 12A12 Paragraph 4.9.1.1

MIL-P-55640 Defect 12A12 Paragraph 4.6.1.2.2, 3.6.3, 3.5

MIL-P-50884 Defect 105 Paragraph 4.7.1.1, 3.15,2.1

2.3.1.3 Description

The circuit will have areas where there is no plating or more commonly areas where the plating is sufficiently thin to be tinted by the basic metal underneath. These areas will appear to be stained or discolored.

2.3.1.4 Cause - The surface to be plated may be contaminated. Variations in current densities across the board caused by improper size and positioning of electrode will also result in thin areas.

2.3.1.5 Corrective Action - Check board surfaces for oxides, organic contaminant, or cleaning abrasives such as pumice that may become embedded in the copper. Survey plating distribution to determine if uniform plating is being accomplished. Check resist for bleedout.

2. Detail Boards

2.3 Plating

2.3.2 Defect - Whisker

2.3.2.1 Definition - A slender acicular metallic growth which occurs after the printed board has been manufactured.

2.3.2.2 Reference Specifications

MIL-P-55110 Defect 12A24 Paragraph 4.9.1.1, 3.6

MIL-P-55640 Defect 12A24 Paragraph 4.6.1.2.2

MIL-P-50889 Defect 111 Paragraph 4.7.1.1, 3.6

2.3.2.3 Description

Spike like protrusions of solder which occur after soldering or a slender metallic growth which propagates from pure tin, copper, silver, and other platings.

2.3.2.4 Cause - Solder whiskers result from poor control of the wave solder process. Such factors as too low solder temperature, contaminated board surface, or contaminated solder will cause solder whiskers to remain after wave soldering. Whiskers will form from other metal if enclosed in hermetically sealed containers and the metals are pure. Such materials are tin, cadmium, and silver.

2.3.2.5 Corrective Action - Review soldering process with emphasis on time and temperature of the board through the solder wave. Review board cleaning procedures to ensure that all contaminants have been removed prior to soldering. Reflow tin or plate with inclusions of other metals such as antimony. Treat cadmium with a conversion coating. Do not enclose phenolic bearing plastics with these metals in hermetically sealed containers.

2. Detail Boards

2.3 Plating

2.3.3 Defect - Overhang on Conductor Edges

2.3.3.1 Definition - Overhang is the increase in conductor width, caused by plating buildup. It is measured from one side of a conductor.

2.3.3.2 Reference Specification

MIL-P-55110 Paragraph 3.5.2.1

MIL-P-55640 Paragraph 3.6.9

MIL-P-50884 Paragraph 3.5.1

2.3.3.3 Description

When viewed at the cross section of the conductor, overhang is that portion of the plating resist which extends beyond the conductor as measured at the laminate surface.

2.3.3.4 Cause - When supplementary plating is allowed to exceed normal limits, the plating will build up around the edges of the conductor and thus add to its width. The most significant increase comes due to plated through hole plating.

2.3.3.5 Corrective Action - Review Master Drawing and Master Pattern to ensure that sufficient allowance has been made for normal plating increases. Investigate plating steps to determine if each conforms to acceptable limits. Too much time or excessive current density are the most frequent causes for overplating.

2. Detail Boards

2.4 Holes, Unplated

2.4.1 Defect - Spacing of holes not as specified

2.4.1.1 Definition - The spacing of adjacent terminal holes shall be such that the holes meet the spacing requirements of the master drawing.

2.4.1.2 Reference Specifications

MIL-P-55110 Defect 12A16 Paragraph 4.9.1.1

MIL-P-55640 Defect 12A16 Paragraph 4.6.1.2.2

MIL-P-55424 Paragraph 3.7

2.4.1.3 Description

The holes when compared with the master pattern do not match the required locations. They may be only slightly displaced or may be an entire grid out of position.

2.4.1.4 Cause - If several boards are stack drilled, there is a tendency for the drill to wander, particularly if the feed rate is too high. The result is a deviation from the required position of the holes in the lower boards. If holes are displaced to another grid position, it is usually caused by an incorrect instruction to the drill machine such as by an automatic tape or through manual control by the operator.

2.4.1.5 Corrective Action - Check drilling procedures to ensure that the workpiece is properly positioned and firmly held while the drilling is underway. Do not stack drill to the extent that the drill bit may deviate from the intended position. Review feed and speed relationships of the drilling operation. Check drill tapes and other drill machine controls.

2. Detail Boards

2.4 Holes, unplated

2.4.2 Defect - Size not as specified

2.4.2.1 Definition - The diameter of unsupported terminal holes shall not exceed by more than 0.020 inch the diameter of the lead to be inserted. The number of different hole sizes shall be kept to a minimum. The inside diameter after plating of the plated through holes shall be no more than 0.028 inch greater than the diameter of the lead which is to be inserted. Unless otherwise specified, the hole size shall be the finished plated size. The diameter of holes in which eyelets are inserted shall not exceed the outside diameter of the barrel of the eyelet by more than 0.010 inch.

2.4.2.2 Reference Specifications

MIL-P-55110 Defect 12B19 Paragraph 4.9.1.1

MIL-P-55040 Defect 12B19 Paragraph 4.6.1.2.2

MIL-P-50884 Defect 202 Paragraph 4.7.1.1

2.4.2.3 Description - See Definition above.

2.4.2.4 Cause - Improper drill size, dull drills, excessive chemical cleaning or movement of board during drilling will result in oversized holes.

2.4.2.5 Corrective Action - Review all drilling operations. Determine that drill bit size has been properly selected. Check chemical cleaning procedure with particular emphasis on the strength of the solution and the time in the solution. Ensure that the board is firmly clamped during drilling to prevent movement.

2. Detail Boards

2.4 Holes, unplated

2.4.3 Defect - Terminal Hole Defects

2.4.3.1 Definition - The hole shall be clean-cut with no visible chipping or cracking in the wall of the holes and there shall be no bulging around the holes or reduction of the hole diameters with base laminate materials such as fibers. The metal foil shall be clean-cut and shall not be deformed into the hole, torn, or lifted.

2.4.3.2 Reference Specifications

MIL-P-55110 Defect 12A22 Paragraph 4.9.1.1, 3.15

MIL-P-55640 Defect 12A22 Paragraph 4.6.1.2.2

MIL-P-50884 Paragraph 3.15

2.4.3.3 Description

The terminal area around the hole will be flared or otherwise deformed. The hole may have irregular walls with particles of resin or glass fibers torn from the surface.

2.4.3.4 Cause - These defects are caused by one or several factors involved in the drilling process. The drill may be dull, the feed may be too fast, the speed may be too slow, or the drill may not be of the proper design for removal of chips and fibers.

2.4.3.5 Corrective Action - Inspect drill bits for sharpness and the proper point angle. Check feed and speed with respect to board material and hole size. Maintain a log of drill use and discard or resharpen drills when required. Check pressure foot load; it must be sufficient to hold the board firmly during the entire drilling operation. Check the backup material to ensure the proper support of the back surface of the board during drilling.

2. Detail Boards

2.5 Holes, plated through

2.5.1 Defect - Plated Through Hole Voids

2.5.1.1 Definition - The area of absence of a specific metal from a specific cross sectional area. When viewing the plated through holes as cross sectioned through the vertical plane, the specific area is the product of the average thickness of the plated metal times the thickness of the board itself as measured from the outermost surfaces of the base copper on external layers. When viewing the plated through hole as cross sectioned through the horizontal plane (annular method), the specific area is the difference between the area of the hole and the area of the outside diameter of the through hole plating.

2.5.1.2 Reference Specification

MIL-P-55110 Defect 12A4 Paragraph 4.9.1.1

MIL-P-55640 Defect 12A2 Paragraph 4.6.1.2.2

MIL-P-50884 Defect 117 Paragraph 4.7.1.1, 3.15.2.2

2.5.1.3 Description

The voids in plated through plating are essentially spherical in shape and may vary from single voids which are almost invisible to multiple voids which traverse the total width of the plating.

2.5.1.4 Cause - Voids occur in plated through holes when an impurity remains attached to the hole wall during plating. Incomplete activation of the resin-glass surface prior to plating may also cause the plating to bridge this area, resulting in a gap between the plating and the hole wall.

2.5.1.5 Corrective Action - Review drilling and hole cleaning operations. Ensure that post drilling cleaning techniques are in fact removing drill particles. Inspect storage and handling equipment and procedures for possible contamination from nearby operations. Maintain agitation of the plating bath and lateral motion of the board throughout the plating operation to prevent accumulation of gas bubbles in the hole.

2. Detail Boards

2.5 Holes, Plated through

2.5.2 Defect - Resin smear

2.5.2.1 Definition - Resin which has been deposited on edges of copper in holes during drilling, either as uniform coating or scattered patches. The resin smear is undesired since it can electrically isolate the conductive layers from the plated-through hole interconnections.

2.5.2.2 Reference Specifications

MIL-P-55640 Paragraph 3.5

MIL-P-50884 Defect 115 Paragraph 4.7.1.1, 3.15

2.5.2.3 Description - A separation between the conductors or terminal areas and the hole plating in a cross sectioned plated through hole. Close examination will reveal resin filling the separation. This resin was heated during the drilling operation and dragged or smeared over the terminal area by the drill.

2.5.2.4 Cause - Resin smear is the result of a combination of drill bit feed and speed conditions and resin softening point which causes the resin to be dragged over innerplane conductors. The resin will soften when the drill bit becomes hot due to a dull or improperly sharpened bit or too rapid a feed with respect to drill speed.

2.5.2.5 Corrective Action - Review all drilling procedures. Develop control of drill usage so that the number of holes drilled by each bit is known and does not exceed the point at which the bit becomes dull. Select drill feed and speed to prevent heating of the resin to the point at which it is plastic. This temperature can be 110°C or less for some resin systems. Chemically clean holes after drilling.

2. Detail Boards

2.5 Holes, Plated through

2.5.3 Defect - Nodules

2.5.3.1 Definition - Rounded lumps which grow during the electroplating process (causing reduction in hole diameter to less than specified on the master drawing).

2.5.3.2 Reference Specification

MIL-P-55640 Defect 12A26 Paragraph 4.6.1.2.2, 3.5

2.5.3.3 Description - Spherical and semispherical lumps protrude from the surface of the hole plating. They may vary from light lumps to many large spherical growths which drastically reduce the hole diameter.

2.5.3.4 Cause - Nodules are caused by too high current density in the area involved or by improper cleaning prior to sensitization and plating. Poor circulation in the hole will also contribute to nodules.

2.5.3.5 Corrective Action - Review all plating and preparation steps. Ensure that the hole is free of particles and contaminants that would prevent proper wetting of the surface by the preplating activators. Current density across the board should be uniform and can be improved through the use of theives. Maintain agitation of the plating bath at a high level and keep adequate circulation of the solution through the hole to ensure uniformity of plating.

2. Detail Boards

2.5 Holes, Plated through

2.5.4 Defect - Separation of conductor, interfaces

2.5.4.1 Definition - Void between terminal area and plated through hole barrel.

2.5.4.2 Reference Specifications

MIL-P-55110 Defect 12A4 Paragraph 4.9.1.1

MIL-P-55640 Defect 12A2 Paragraph 4.6.1.2.2, 3.5

2.5.4.3 Description - When a plated through hole is viewed in cross section, a gap appears between the barrel plating and the terminal area on the outer layers or the internal layers of a multilayer board. When the terminal area is cross sectioned horizontally, the gap may be a local separation or may occur around the entire circumference of the terminal area inside diameter.

2.5.4.4 Cause - Separation may be caused either by a contaminant remaining on the terminal area during plating of the hole or may result from thermal stresses which are sufficient to cause the separation.

2.5.4.5 Corrective Action - Review preplating cleaning procedures. Cleaning solutions containing abrasive may leave deposits on the terminal area. Resin smear will result in separation and can be corrected as noted under that defect. Weakly bonded electroless plating at the terminal area to hole plating interface will result in a separation during thermal shock or thermal cycling. Check catalyzing processes and electroless plating solutions and procedures.

2. Detail Boards

2.6 Eyelets and Terminals

2.6.1 Defect - Broken and/or part of Eyelet missing

2.6.1.1 Definition - Part of eyelet missing, circumferential splits.

2.6.1.2 Reference Specifications

MIL-P-55110 Defect 12A2 Paragraph 4.9.1.1

2.6.1.3 Description - A well formed eyelet will exhibit a smooth uniformly rolled over seat; however, if the material or tooling is not correctly selected or adjusted, the seat may exhibit splits which progress from the outer circumference into the barrel. In severe cases the splits may be close together and the material bounded by them may break off.

2.6.1.4 Cause - The eyelet material must be sufficiently ductile to enable it to be rolled over without cracking. The material may become hardened during machining, may include impurities which cause localized embrittlement, or may be of the wrong temper. These conditions will make the material susceptible to cracking. Heavy nonductile plating of nickel will also cause cracking of the basic metal if the plating itself cracks. Tooling which causes nonuniform or too severe working of the eyelet seat will also cause splitting. If the forming die is forced to travel beyond that needed to simply roll over the flange, splitting and cracking may occur.

2.6.1.5 Corrective Action - Inspect forming dies and the equipment which holds and drives them. Check for irregularities in the die, pressure increases, and off center forming. If the splitting has occured somewhat abruptly in the production cycle, it may be caused by nonductile plating or hardened terminal material.

2. Detail Boards

2.6 Eyelets and Terminals

2.6.2 Defect - Not Properly Seated

2.6.2.1 Definition - Not perpendicular to the board

2.6.2.2 Reference Specification

MIL-P-55110 Defect 12A3 Paragraph 4.9.1.1

2.6.2.3 Description - The terminal will appear tilted when reviewed from the component side of the board and will exhibit a gap under one side of the terminal base. The seat side may appear normal or may exhibit a severely worked area around the periphery of the seat.

2.6.2.4 Cause - Improperly seated terminals are caused when the board is not held perpendicular to the axis of travel of terminal during the forming operation. This normally happens when a foreign object is between the board and the machine surface plate or if the board is held manually at an angle.

2.6.2.5 Corrective Action - Inspect machine and tooling to ensure that the plate on which the board sets during the terminal forming process is perpendicular to the terminal holding die. Do not attempt to manually hold the board unless fixtures are present to ensure proper positioning of the board.

2. Detail Board

2.6 Eyelets and Terminals

2.6.3 Defect - Soldered improperly

2.6.3.1 Definition - Total voids in solder fillet around eyelet exceeding 20 percent of the periphery in flat flanged eyelets; 20 percent in roll flanged eyelets; or 30 percent of the peripheral area in funnel flanged eyelets. Cracks in solder around eyelet.

2.6.3.2 Reference Specifications

MIL-P-55110 Defect 12A7 Paragraph 4.9.1.1

MIL-P-55640 Defect 12A7 Paragraph 4.6.1.2.2

2.6.3.3 Description - Solder will be missing around the periphery of the eyelet. The remaining solder will appear normal with good wetting and fillets. When the solder is visibly cracked, it will generally also exhibit a frosty area of solder around the crack.

2.6.3.4 Cause - Solder voids are caused by incomplete wetting of the required surfaces by the solder or may be caused when gas such as moisture, solvent, or volatized flux is released in the hole and erupts through the molten solder. Cracks may be caused by thermal cycling of good solder joint or may occur if the eyelet is moved as the solder is cooling.

2.6.3.5 Corrective Action - Dry boards before soldering to dry out any residual or trapped moisture or solvent. Check speed of wave solder machine and use a slower speed or increased board preheat time, thus allowing the board to remain at soldering temperature for a longer time. Protect the board from handling while the solder may still be in the liquid or plastic state.

2. Detail Boards

2.6 Eyelets and Terminals

2.6.4 Defect - Loose Terminal

2.6.4.1 Definition - Any standoff terminal that can be turned or removed by hand.

2.6.4.2 Reference Specifications

MIL-P-55110 Defect 12B21 Paragraph 4.9.1.1

MIL-P-55640 Defect 12B21 Paragraph 4.6.1.2.2

MIL-P-50884 Paragraph 3.12

2.6.4.3 Description - The terminal may appear to be lifted from the board surface on the component side or may not be completely formed on the solder side. In marginal cases the terminal may appear to be seated but when torque is applied by hand, it will rotate.

2.6.4.4 Cause - Improper adjustment and setting of the terminal forming machine. If there is insufficient force from the machine to the forming die, the terminal will not seat tightly. A hole that is too large for the terminal may also prevent a tight forming terminal.

2.6.4.5 Corrective Action - Determine correct hole size for the terminal selected and ensure that the hole in the board is correct. Check the wall thickness and the hardness of terminal since a wall that is too thick or too hard will not form readily. Check all settings on the terminal machine and the condition of the forming die.

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19 REPORT DOCUMENTATION PAGE

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this program was to develop a military standard that contained corrective action guide data for printed wiring board and assembly defects and to develop test data from which revision drafts to MIL-I-46058 could be written.

This report describes the accomplishments of the final portion of the program. It also includes major portions of effort completed in previous semiannual portions of the program. The complete results of all contract goals are provided

Abstract (Continued)

with emphasis placed on reversion, service temperature, and buffer material analysis.

The Phase I portion is provided as an appendix to this report and sets forth those features necessary to achieve the goals selected.

The Phase II effort demonstrated that a quantitative test procedure could be developed that would measure change in properties of the various materials as they age or deteriorate under thermal and moisture conditions. The buffer material tests strongly indicate the need for buffer materials only if coating thicknesses are greater than 6 mils.